

Health Care during Electricity Failures:

Patient Risks, Capacity Shortages, VSL/E, and Risk Chart

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⁷ Global Surgery and Change, Harvard University

ESDD - RESEARCH LAB

ENERGY AND SUSTAINABLE DEVELOPMENT WITH DESIGN

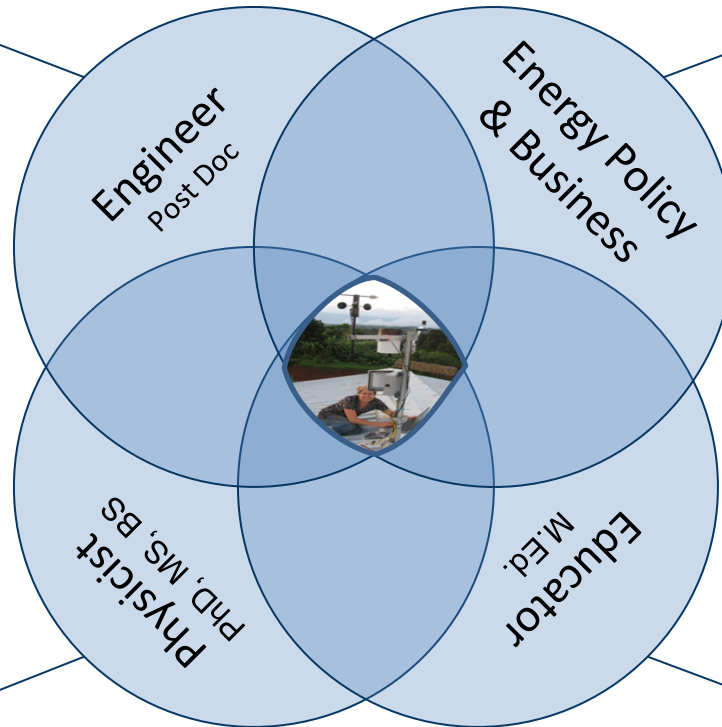
* Today's speaker

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Assistant Teaching Professor, Physics Department, University of Notre Dame

Academic Publications

Energy and Sustainable Development



Academic Publications

Design and Control
Optimization with
Novel Objective for
Power Management

Empower Energy Design

International Organization
to Change
Design Paradigm
Toward Innovation

Energy Curriculum

for Physics, Engineering, Sustainability, and Business Curricula

ESDD - RESEARCH LAB

ENERGY AND SUSTAINABLE DEVELOPMENT WITH DESIGN

Data Collection & Management

Global Standards: Comparability, Sensors, Crowdsourcing/Swarm, Citation/Outside Links from Data Management Location

National Standards: Frameworks, Capacity Transformation

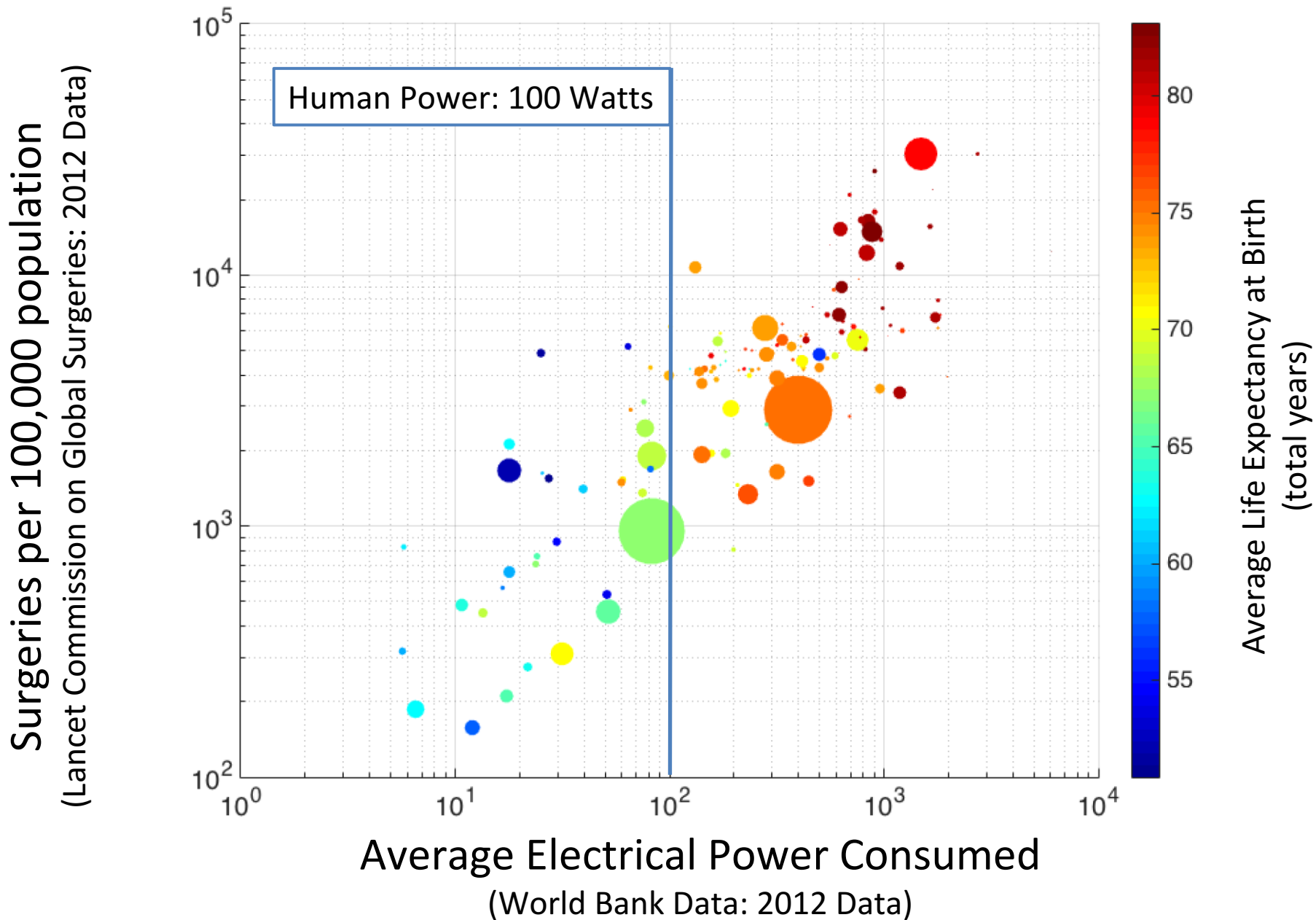
Regional Standards: Networks, Interconnected

Community Standards: Interdependent, Energy Ethics



Foundation: National Energy Database by Ministry of Energy and United Nations [SEforALL](#) – Creative Commons, Uploaded Organization Identification, Energy Ethics Documentation Data Agreement

Global Surgeries vs Average Electrical Power Consumed



Modeling Electricity and Health Care

Part A (sites 1 & 2)

	Iraq - <i>Solar Energy</i> , 2010	Bangladesh - <i>Energy</i> , 2010
	<p>Health Care Load 32 kWh/d 5.6 kW peak</p> <p>Generator 1</p> <p>Converter</p> <p>T-105</p> <p>AC</p> <p>DC</p> <p>PV</p>	<p>Health Care Load 160 kWh/d 32 kW peak</p> <p>WES 5 Tulipo</p> <p>Generator 1</p> <p>Converter</p> <p>T-105</p> <p>AC</p> <p>DC</p> <p>PV</p>
Cost of Electricity (\$/kWh)	\$0.26/kWh	\$0.51/kWh
Energy Capacity Shortage (%) $\frac{E_{not\ served}}{E_{total}}$	18 %	10 %
Time Capacity Shortage (%) $\frac{t_{not\ served}}{t_{total}}$	25 %	6.6 %
Failures (hrs/year)	2160 hours	574 hours
Back-up System	Install Solar no backup chosen	Install Solar+Wind no backup chosen

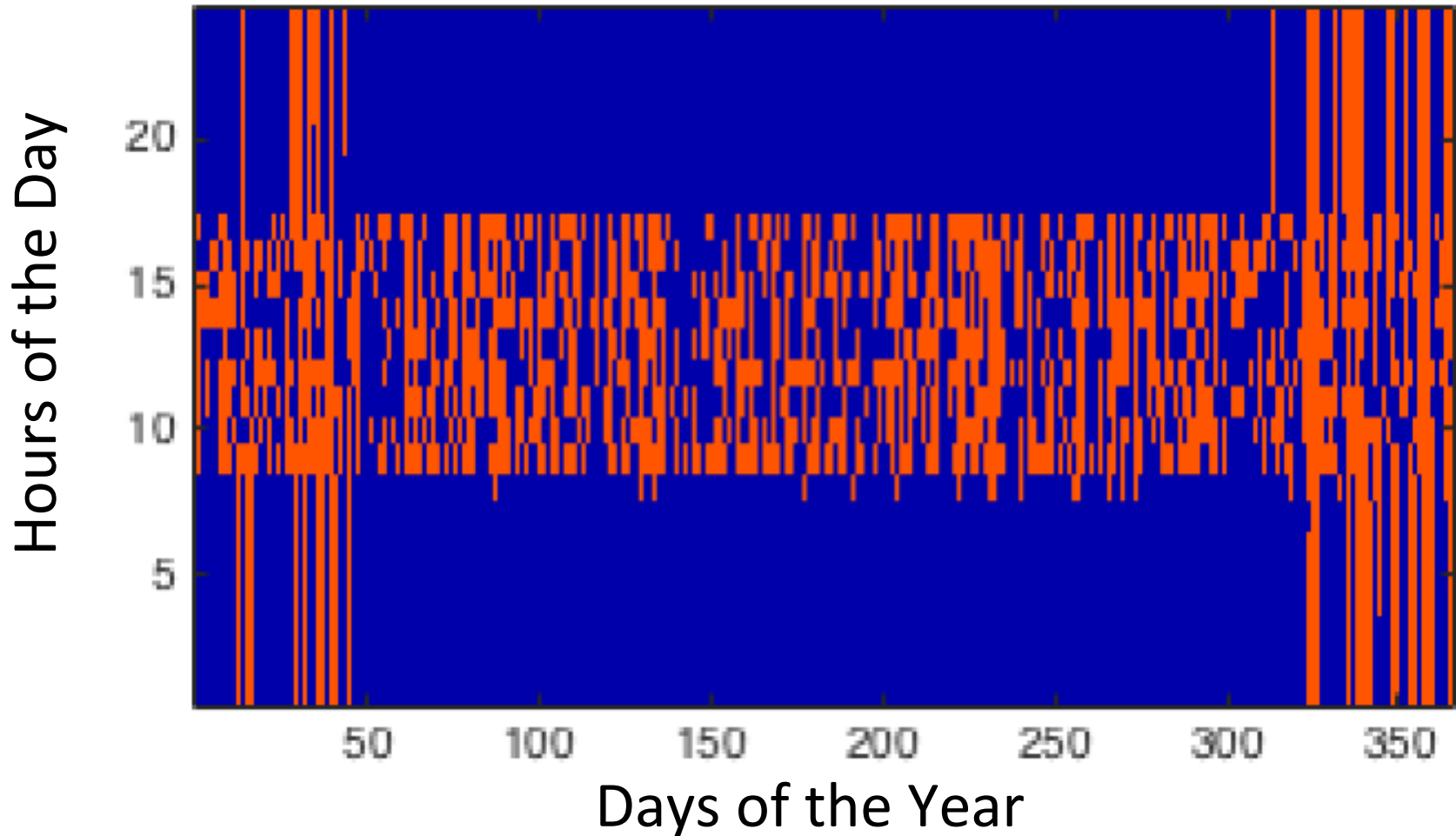
Modeling Electricity and Health Care

Part B (sites 3 & 4)

	Ghana - <i>International Journal of Computer Applications</i> , 2015	Uganda - <i>ISSST-IEEE</i> , 2012
	<p>Hydro</p> <p>Health Care Load 153 kWh/d 12 kW peak</p> <p>AC</p> <p>DC</p> <p>Converter</p> <p>PV</p> <p>BWC Excel-R</p>	<p>Generator 1</p> <p>Health Care Load 30 kWh/d 5.1 kW peak</p> <p>AC</p> <p>Grid</p>
Cost of Electricity (\$/kWh)	\$0.12/kWh	Grid: \$0.25/kWh - Diesel: \$0.75-11/kWh
Energy Capacity Shortage (%) $\frac{E_{not\ served}}{E_{total}}$	11 %	4.1 %
Time Capacity Shortage (%) $\frac{t_{not\ served}}{t_{total}}$	49 %	4.0 %
Failures (hrs/year)	4289 hours	355 hours
Back-up System	Government Grid: Hydro base power, Facilities: Provide their own peak power	Year of Data on Voltage and Current Grid+Diesel Generator

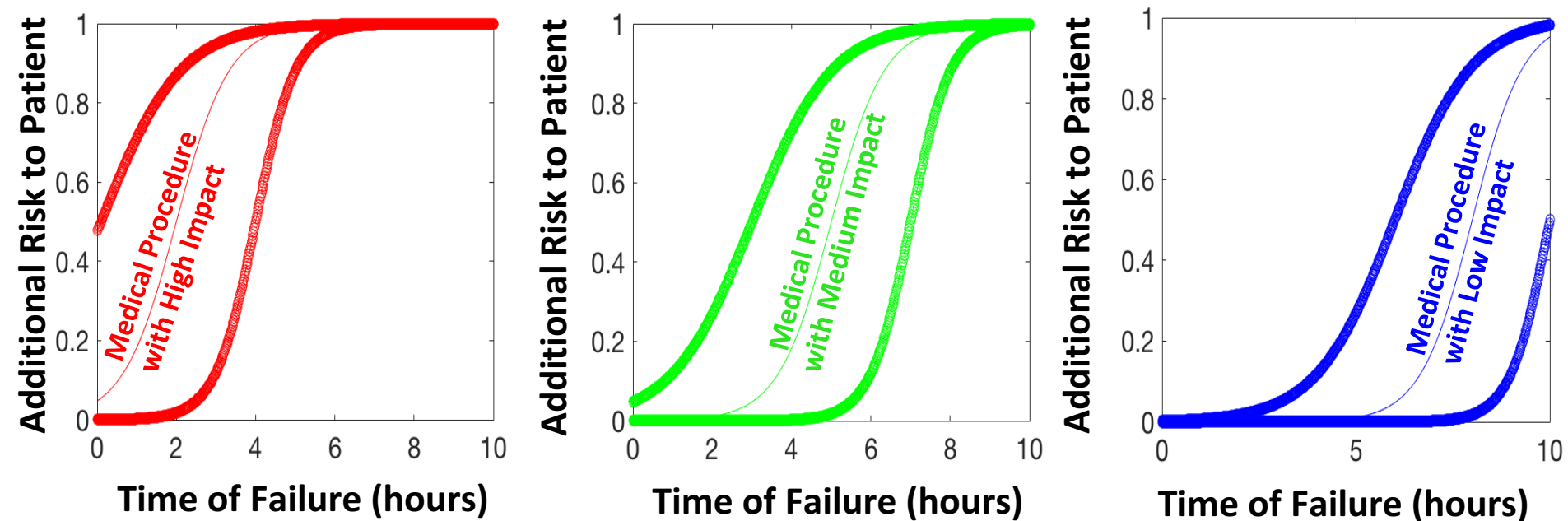
Energy Health Care System Example

$$E(x, t_{year}) = \left\{ \begin{array}{l} \text{Energy Research Data} \end{array} \right\} \left\{ \begin{array}{l} \text{On} = 0 \quad \blacksquare \\ \text{Off} = 1 \quad \blacksquare \end{array} \right.$$



Modeling Electricity and Health Care

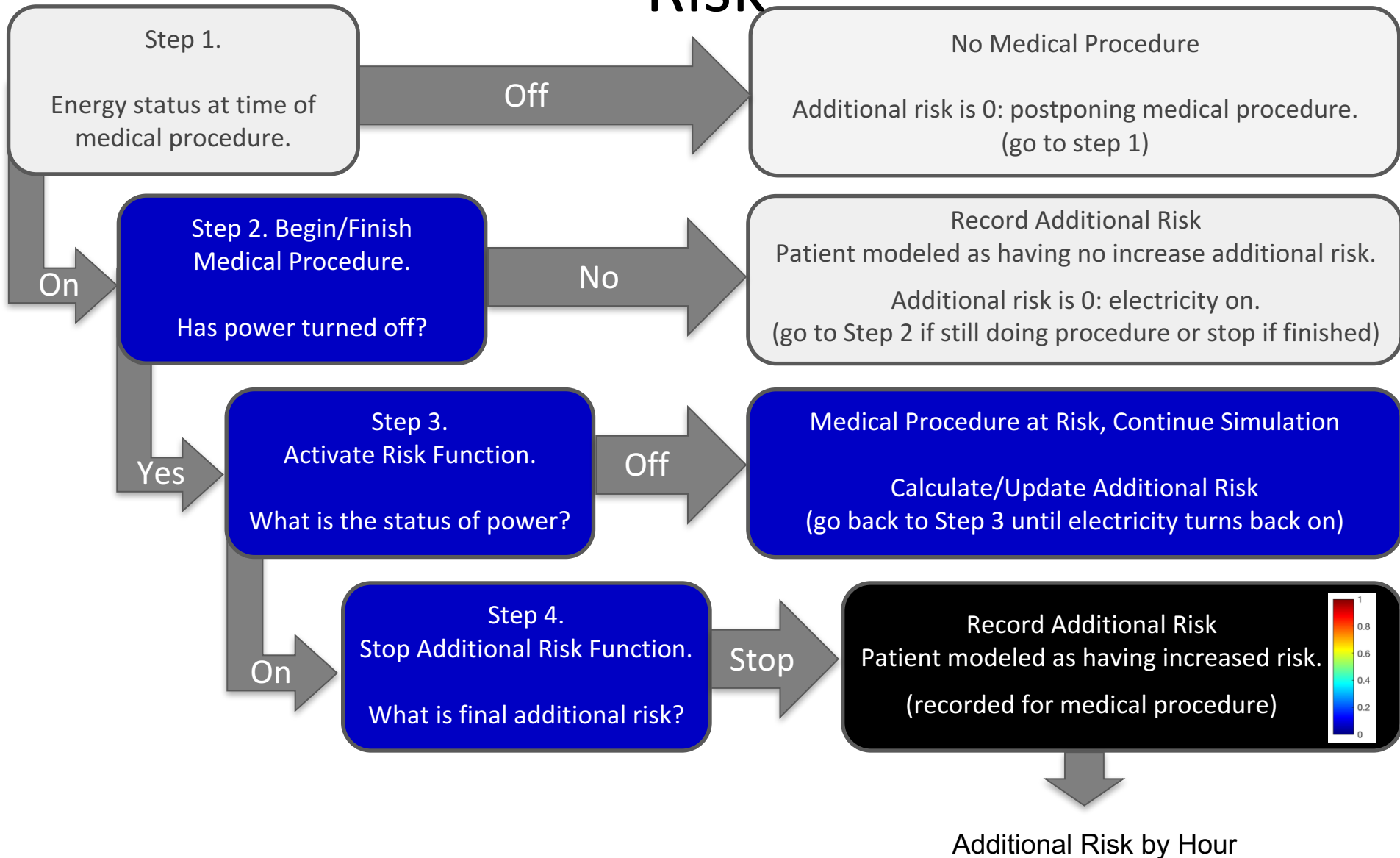
Part B - Additional Risk to Patient



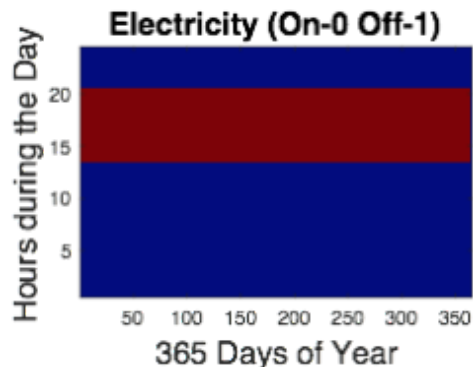
1. Medical Procedures can be placed into three impact categories: high, medium, low
2. Horizontal Axis: duration of electricity failure
3. Vertical Axis: electricity failure duration increases the risk to the patient
 - Patient Additional Risk starts at zero
 - Patient Additional Risk can never be one (certain death), but can approach one

Calculating Medical Procedure Additional Risk

Risk



$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$



Electricity System: Generic Failure from 2pm-8pm Patient Additional Risk

	High Impact Medical Procedures	Medium Impact Medical Procedures	Low Impact Medical Procedures
Maximum	<p>High Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>	<p>Medium Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>	<p>Low Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>
Mean	<p>High Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>	<p>Medium Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>	<p>Low Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>
Minimum	<p>High Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>	<p>Medium Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>	<p>Low Impact (Risk)</p> <p>Hours during the Day (0 to 24)</p> <p>365 Days of Year (0 to 365)</p>

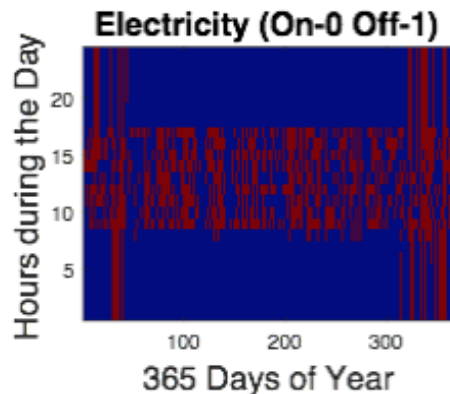
Combining Electricity Failure and Additional Risk to Patient

$$R(h, i, j, t_{energy}, t_{duration}) = E(h, t_{energy})p(i, j, t_{duration})$$

R: Additional Risk to patients during the year which is a matrix of matrices

- E: Energy System which is a function of
 - h: hour of the year
 - t_{energy} : time of the energy system failure
- p: probability of patient death due to failure after medical procedure started
 - i: type of medical procedure (high, medium, low risk to electricity failure)
 - j: type of confidence interval (min, mean, maximum probabilistic curve)
 - $t_{duration}$: duration of time of the energy system failure

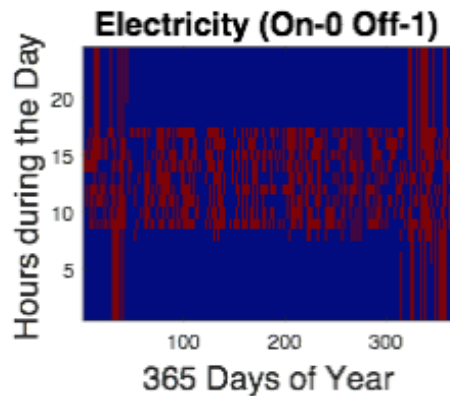
$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$



**Electricity System
Iraq
Solar Panel**

	High Impact Medical Procedures	Medium Impact Medical Procedures	Low Impact Medical Procedures
Maximum	<p>High Impact (Risk)</p> <p>Hours during the Day</p> <p>365 Days of Year</p>	<p>Medium Impact (Risk)</p> <p>Hours during the Day</p> <p>365 Days of Year</p>	<p>Low Impact (Risk)</p> <p>Hours during the Day</p> <p>365 Days of Year</p>
Mean	<p>High Impact (Risk)</p> <p>Hours during the Day</p> <p>365 Days of Year</p>	<p>Medium Impact (Risk)</p> <p>Hours during the Day</p> <p>365 Days of Year</p>	<p>Low Impact (Risk)</p> <p>Hours during the Day</p> <p>365 Days of Year</p>
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$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$

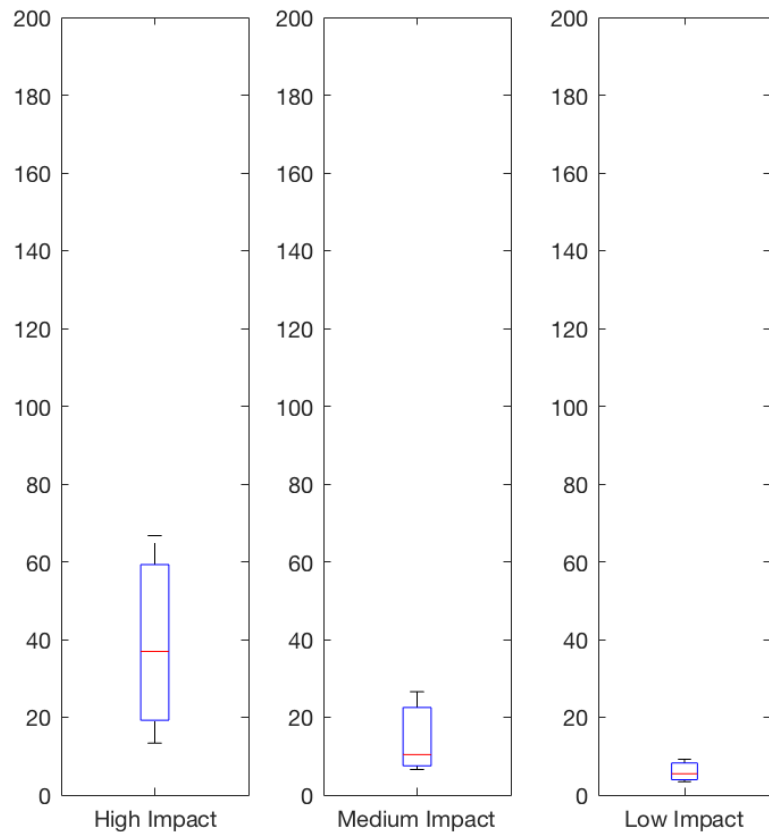


**Electricity System
Iraq
Solar Panel**

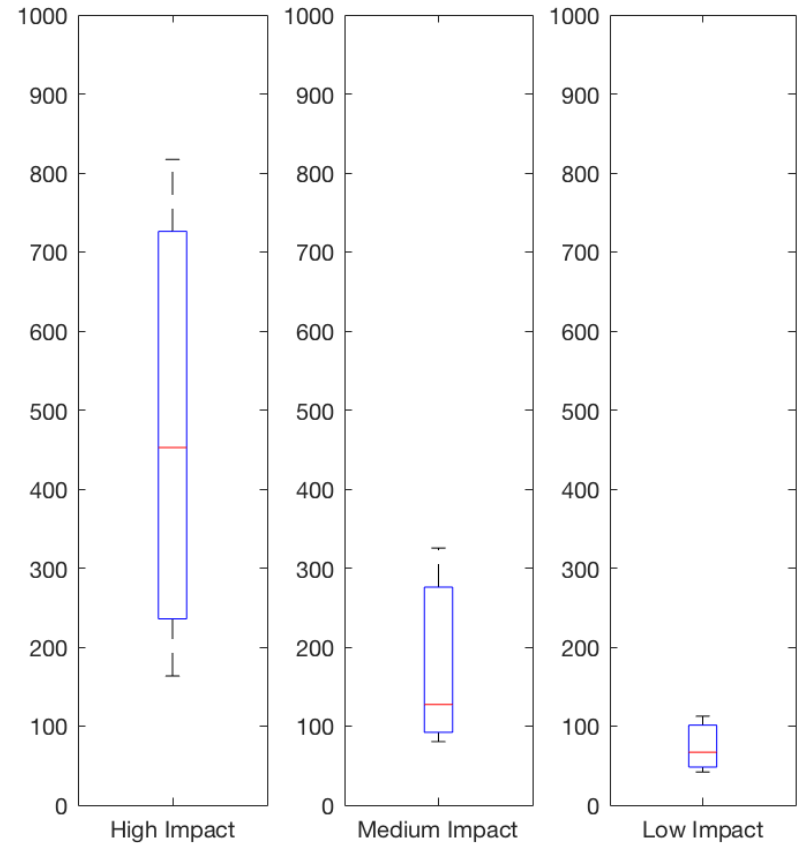
Deleting Postponing Procedures	High Impact Medical Procedures	Medium Impact Medical Procedures	Low Impact Medical Procedures
Maximum			
Mean			
Minimum			

Solar Powered Health Center

Patient Deaths per 1,000
over the year of events: 8760 hr

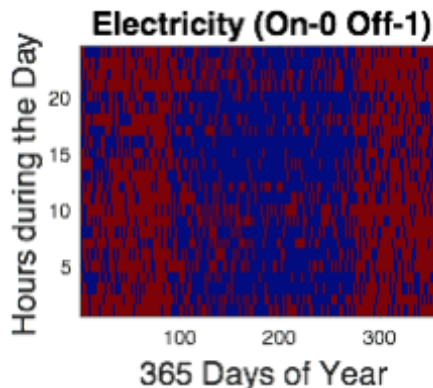


Patient Deaths per 1,000
over electricity outage events

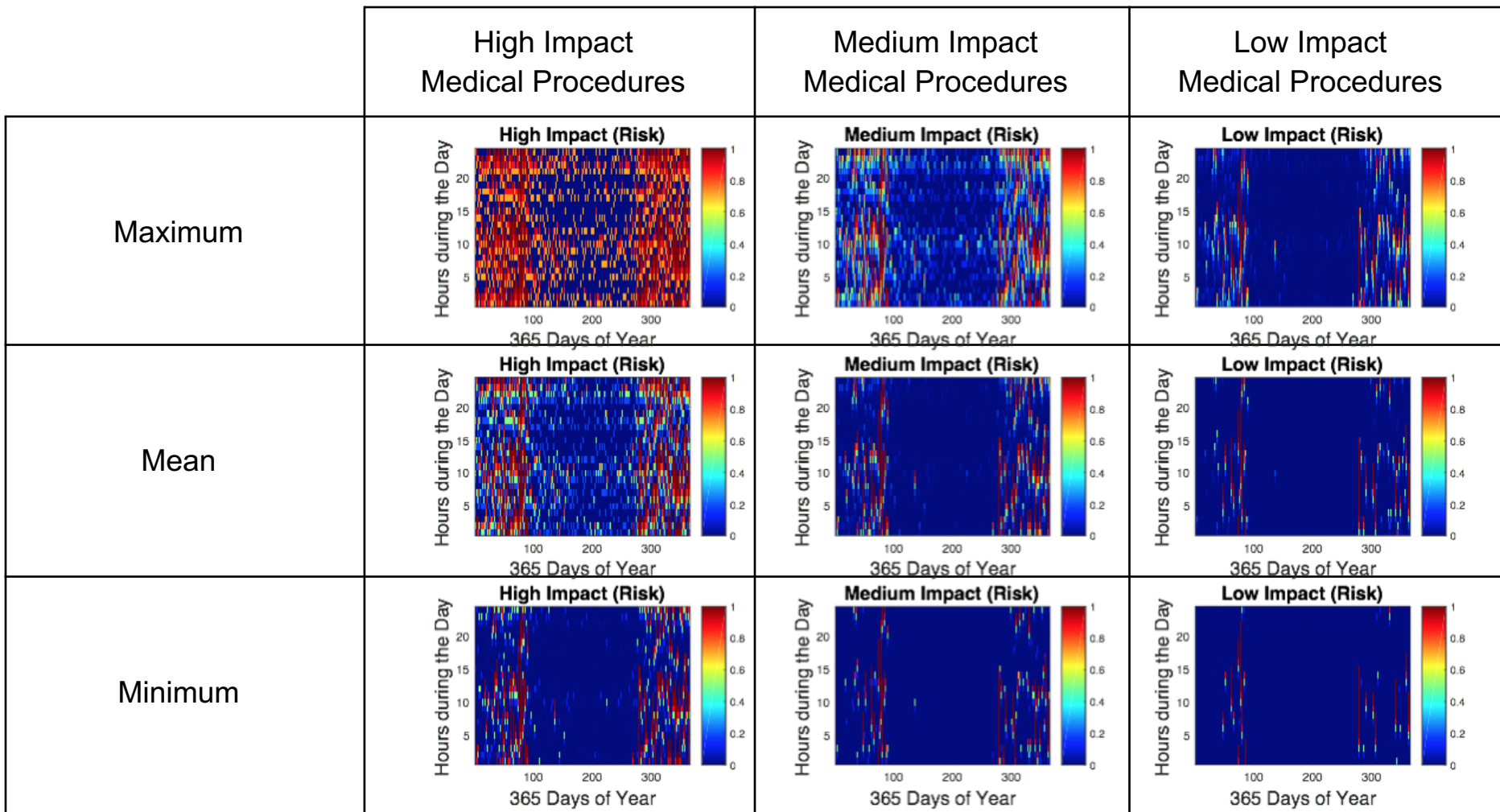


Note: The number of patient deaths per 1,000 over the entire year (electricity on and off events) is small compared to the number of patient deaths per 1,000 for those who experience a failure (only electricity off events) during their medical procedure.

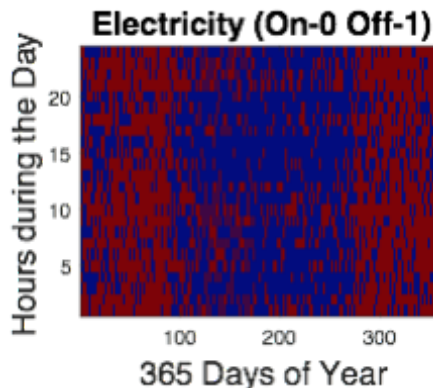
$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$



**Electricity System
Ghana
Hydroelectric**



$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$

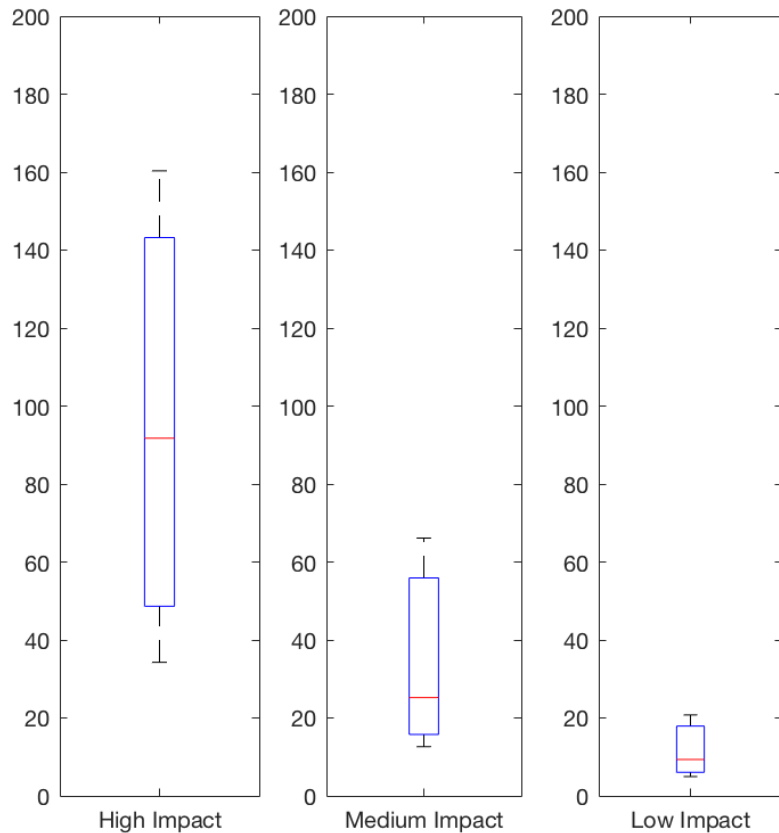


**Electricity System
Ghana
Hydroelectric**

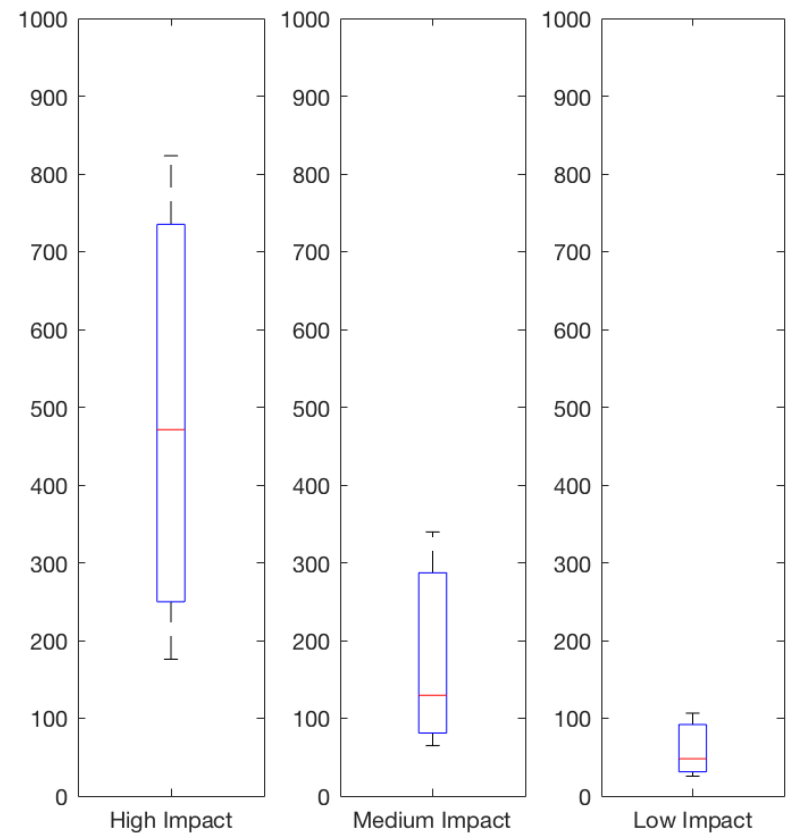
Deleting Postponing Procedures	High Impact Medical Procedures	Medium Impact Medical Procedures	Low Impact Medical Procedures
Maximum	<p>High Impact (Events)</p>	<p>Medium Impact (Events)</p>	<p>Low Impact (Events)</p>
Mean	<p>High Impact (Events)</p>	<p>Medium Impact (Events)</p>	<p>Low Impact (Events)</p>
Minimum	<p>High Impact (Events)</p>	<p>Medium Impact (Events)</p>	<p>Low Impact (Events)</p>

Hydro Powered Health Center

Patient Deaths per 1,000
over the entire year

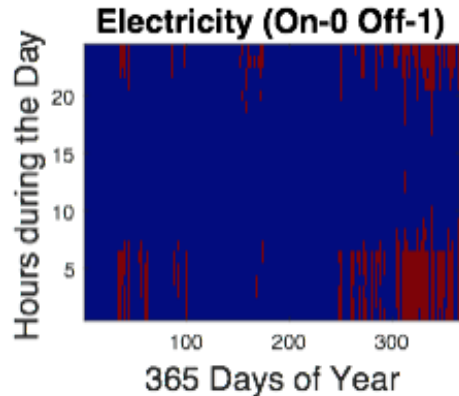


Patient Deaths per 1,000
over electricity outage events



Note: The number of patient deaths per 1,000 over the entire year (electricity on and off events) is small compared to the number of patient deaths per 1,000 for those who experience a failure (only electricity off events) during their medical procedure.

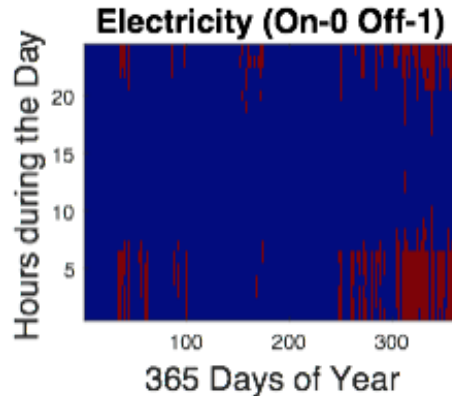
$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$



**Electricity System
Bangladesh
Solar and Wind**

	High Impact Medical Procedures	Medium Impact Medical Procedures	Low Impact Medical Procedures
Maximum			
Mean			
Minimum			

$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$

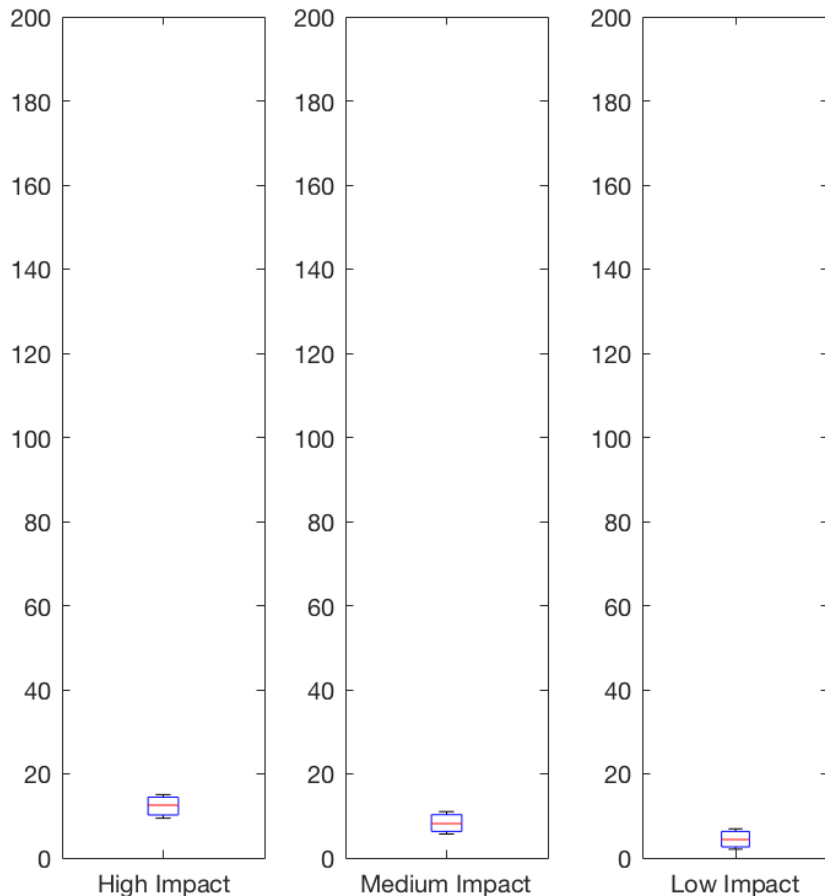


**Electricity System
Bangladesh
Solar and Wind**

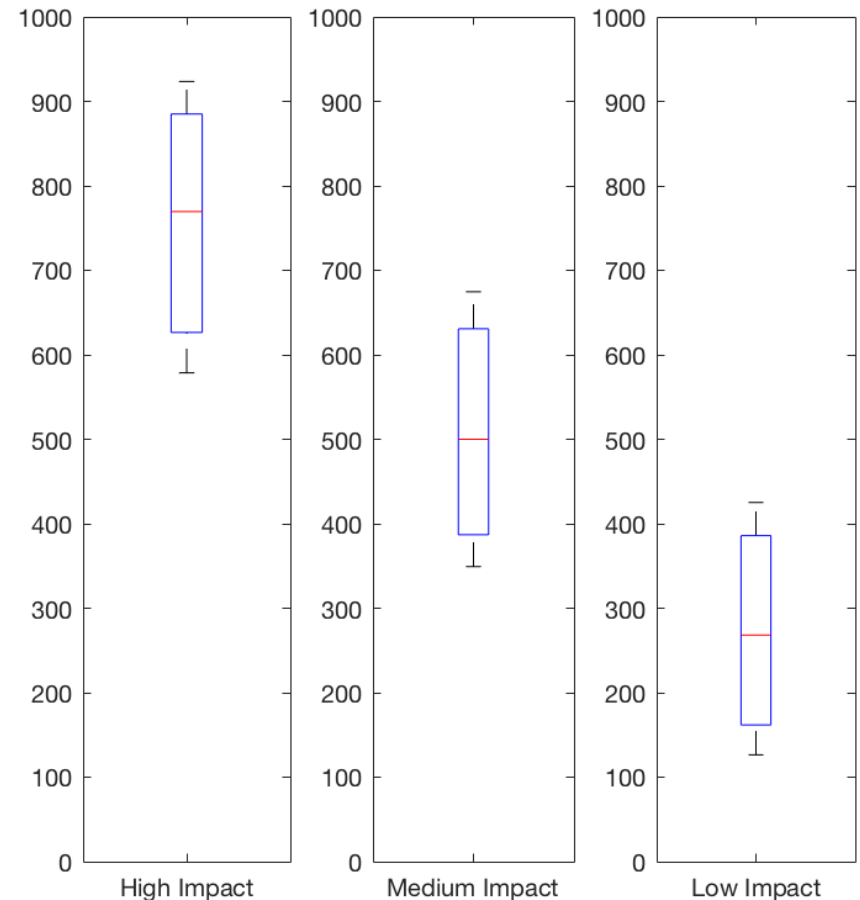
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Solar + Wind Powered Health Center

Patient Deaths per 1,000
over the entire year

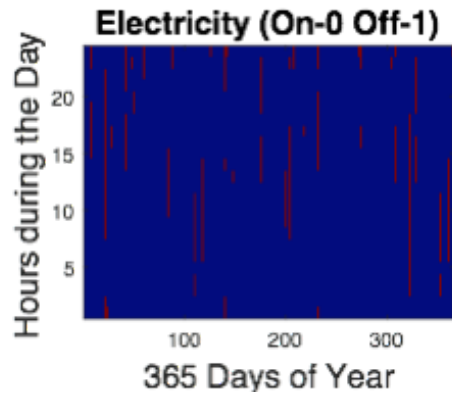


Patient Deaths per 1,000
over electricity outage events

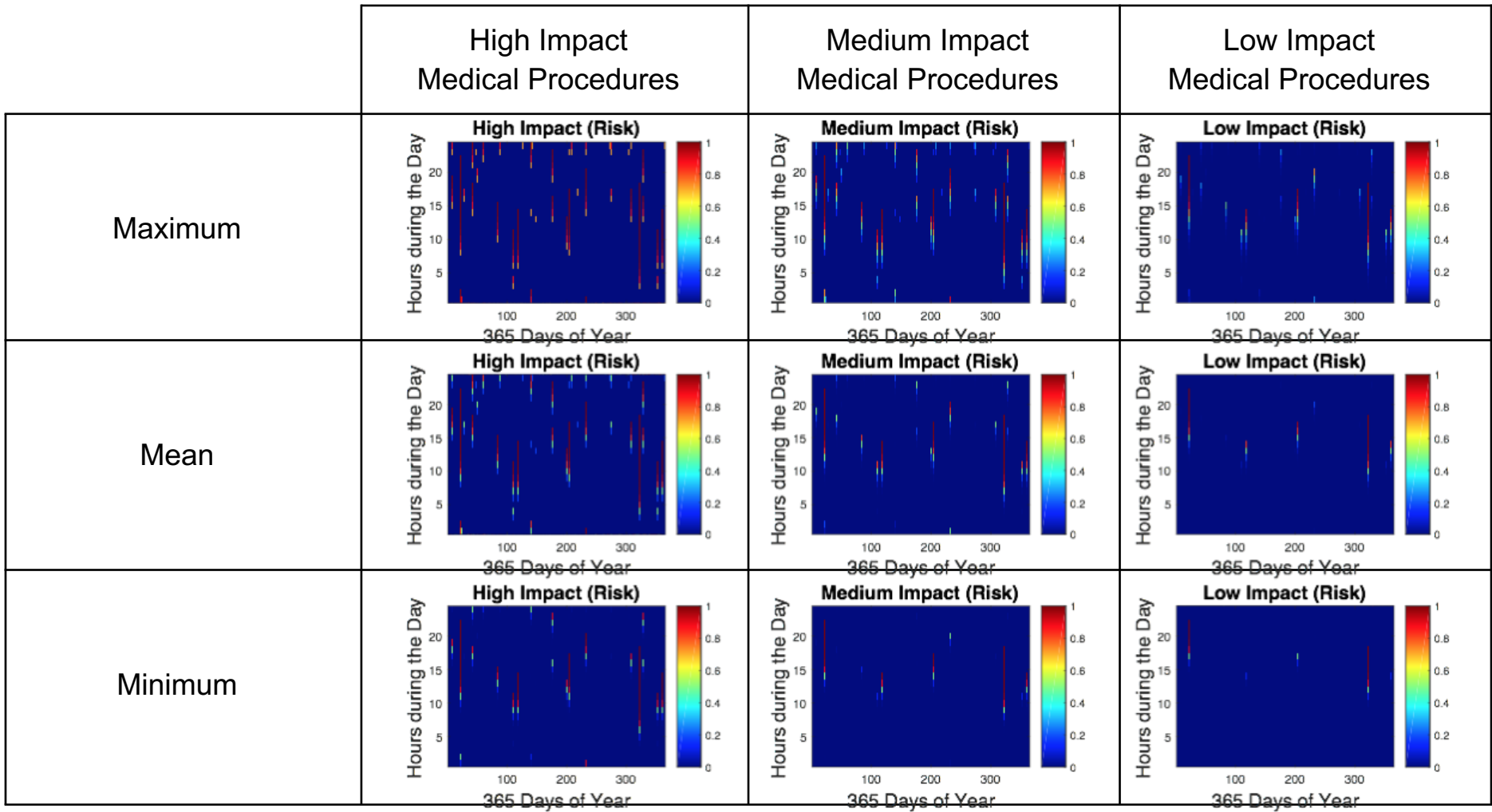


Note: The number of patient deaths per 1,000 over the entire year (electricity on and off events) is small compared to the number of patient deaths per 1,000 for those who experience a failure (only electricity off events) during their medical procedure.

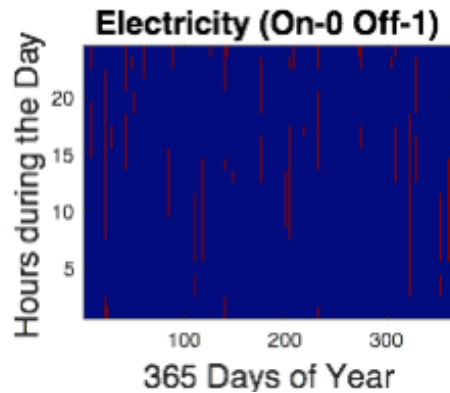
$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$



**Electricity System
Uganda
Grid and Diesel Generator**



$$E(x, t_{year}) = \begin{cases} On = 0 & \text{Blue} \\ Off = 1 & \text{Red} \end{cases}$$

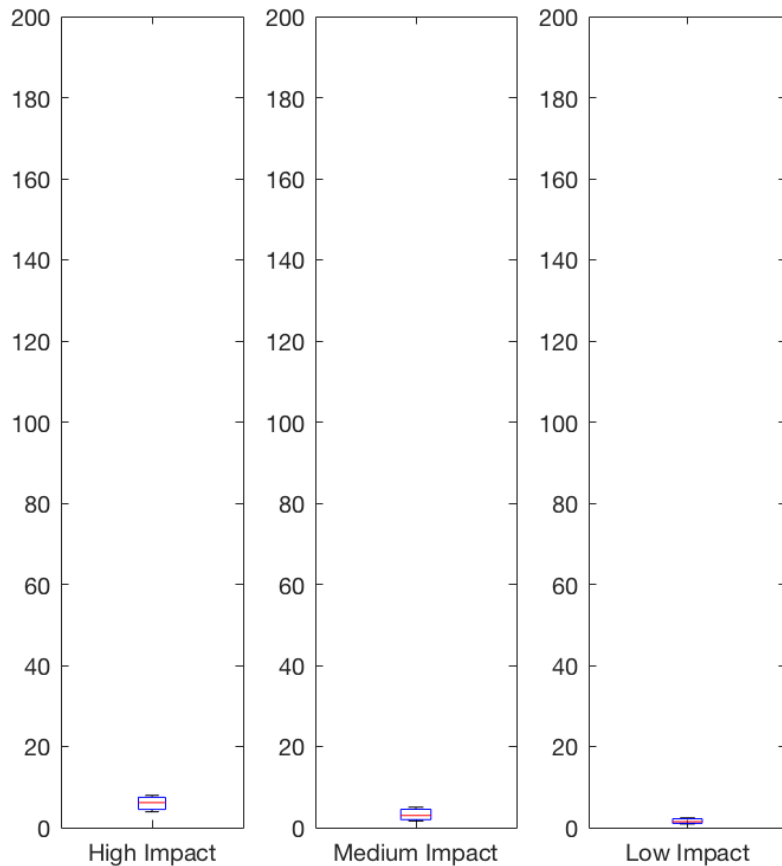


**Electricity System
Uganda
Grid and Diesel Generator**

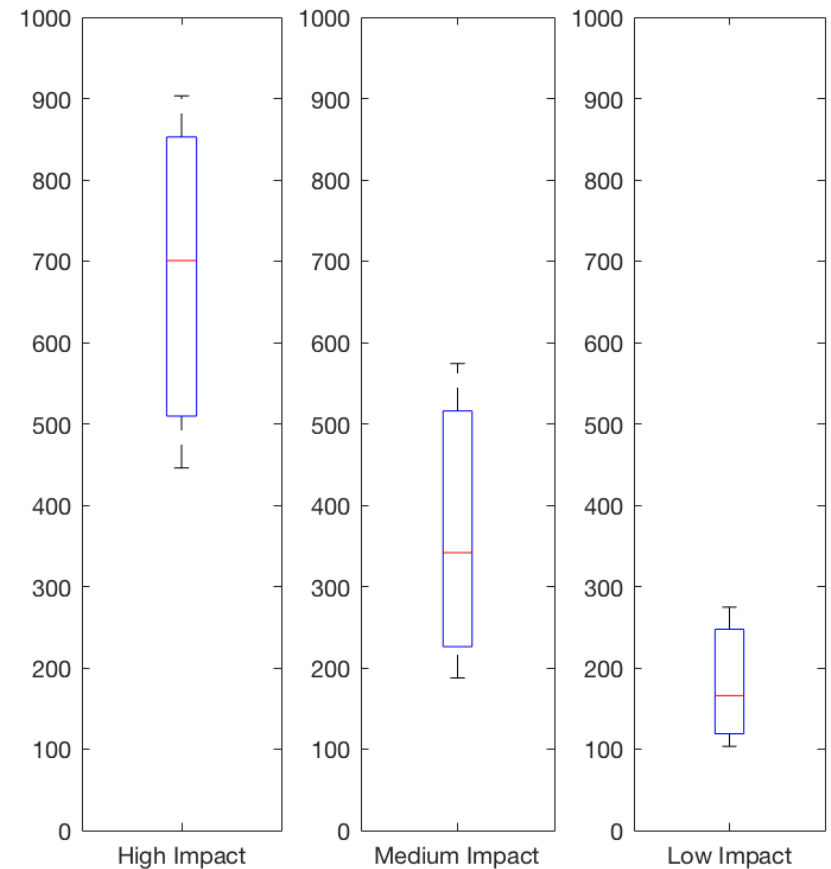
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Grid+Diesel Powered Health Center

Patient Deaths per 1,000
over the entire year



Patient Deaths per 1,000
over electricity outage events



Note: The number of patient deaths per 1,000 over the entire year (electricity on and off events) is small compared to the number of patient deaths per 1,000 for those who experience a failure (only electricity off events) during their medical procedure.

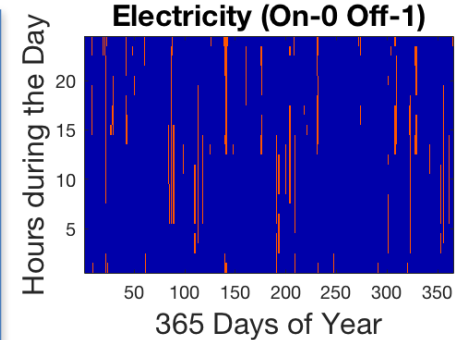
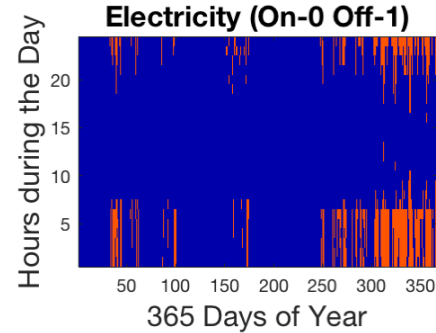
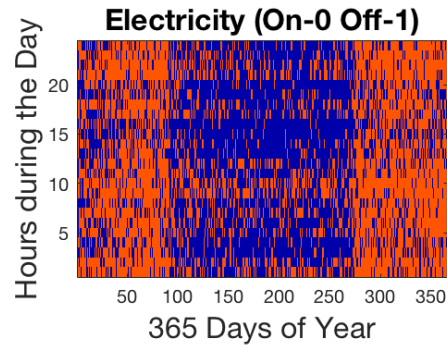
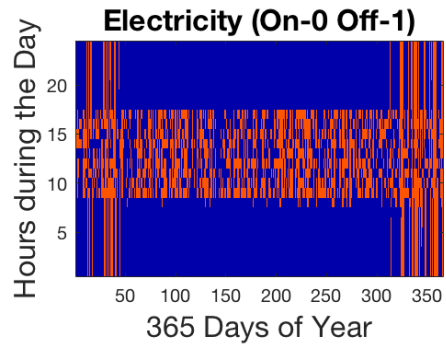
Energy Health Systems Comparisons

Solar Only

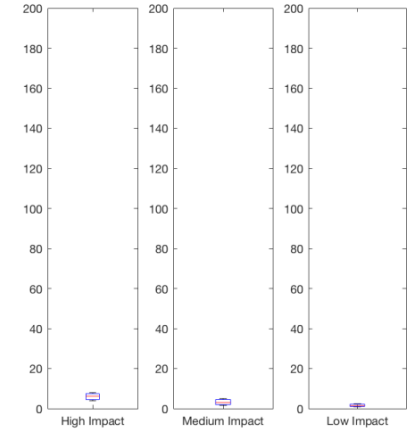
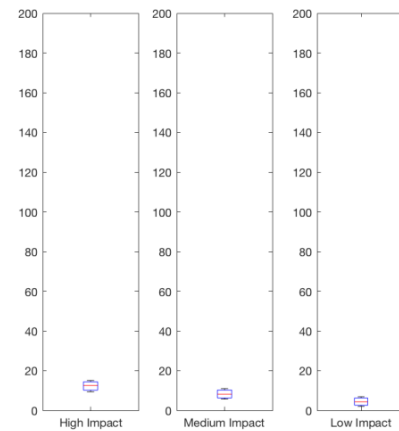
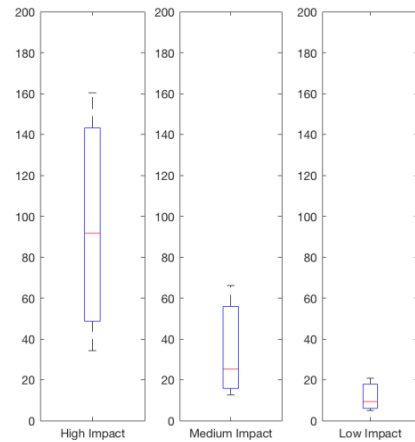
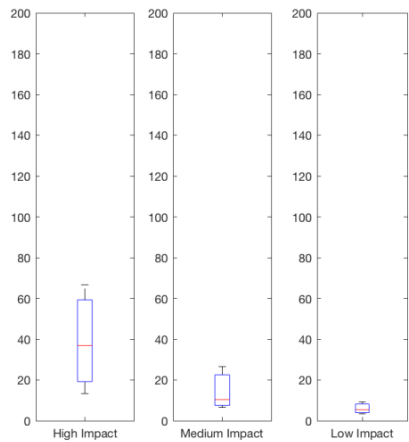
Hydro Only

Solar+Wind

Grid+Diesel



Deaths per 1,000 Patients



Deaths per 1,000 over the entire year, but only considers the final additional risk (deleted all risks explained from postponing).

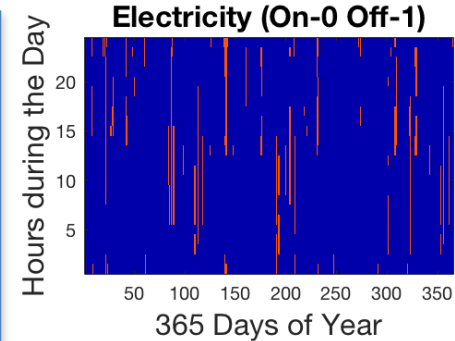
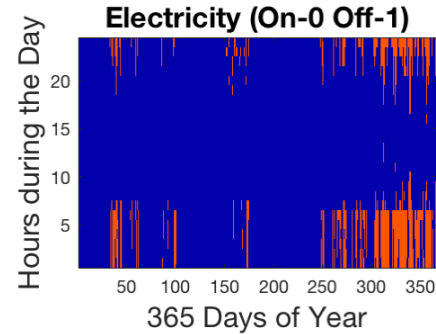
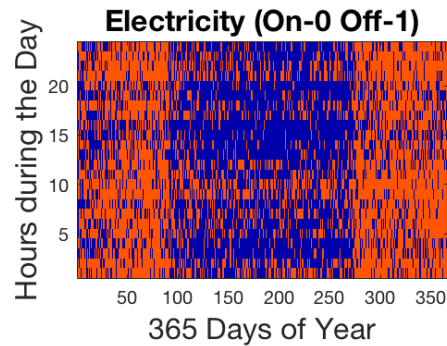
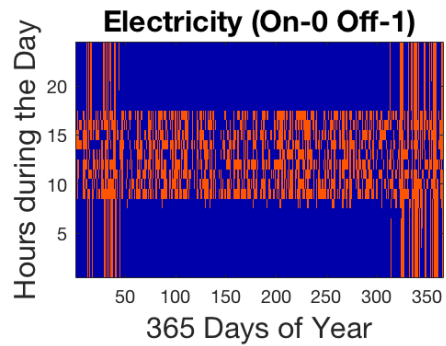
Energy Health Systems Comparisons

Solar Only

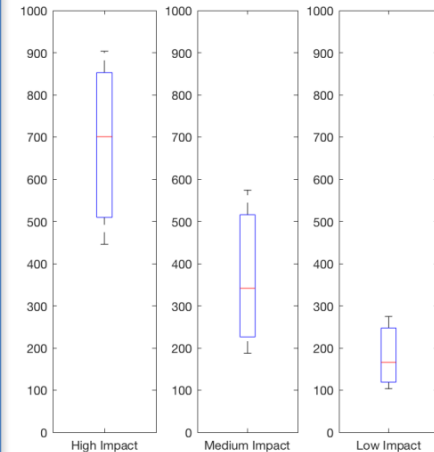
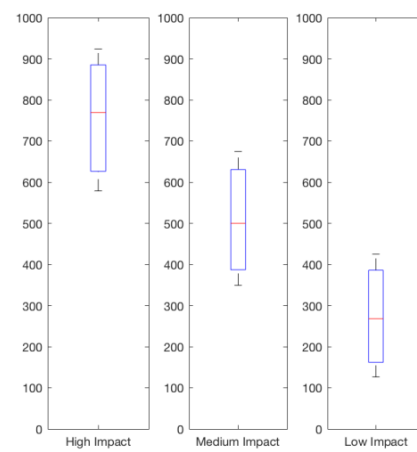
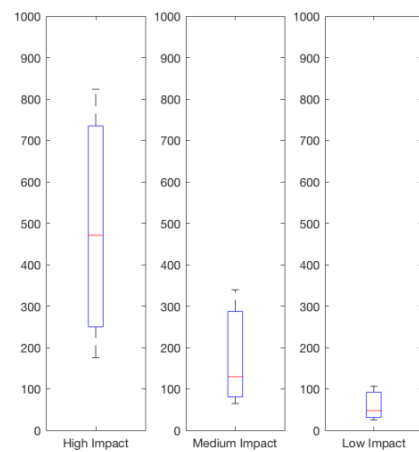
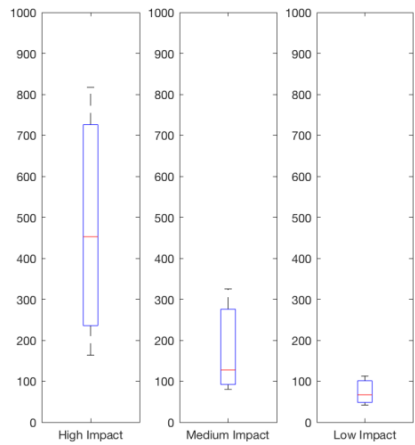
Hydro Only

Solar+Wind

Grid+Diesel



Deaths per 1,000 Patients Experiencing Electricity Failures



Deaths per 1,000 over the entire year, but only considers the final additional risk (deleted all risks explained from postponing).

Health Care + Electricity Simulation Model

C. Medical Procedure Types:

- % of High Impact Procedures
- % of Medium Impact Procedures
- % of Low Impact Procedures
- % of No Impact Procedures

D. Size of Health Care Facility

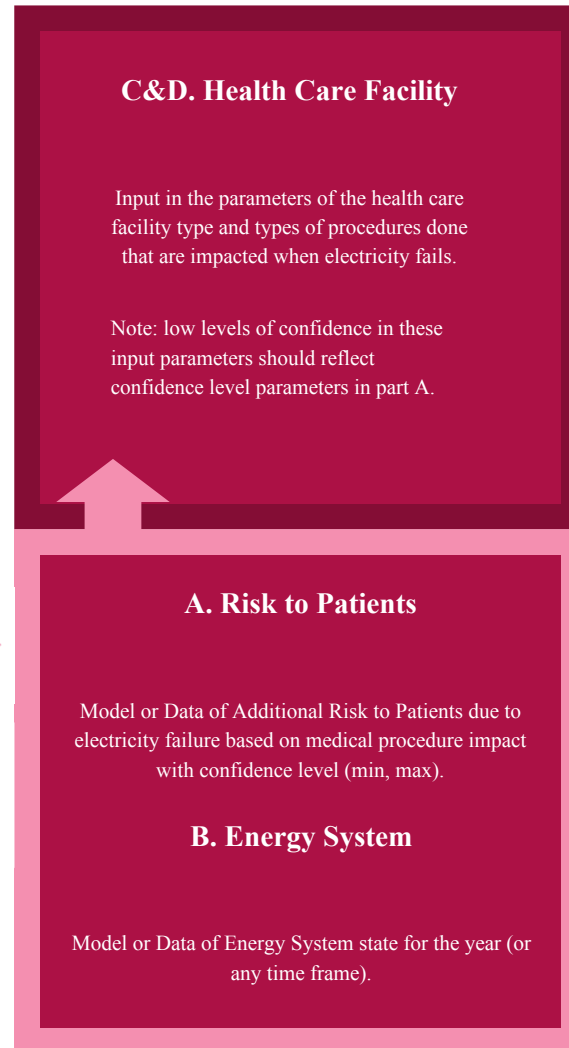
- Number of Patients/year
- or Number of beds (to above)

A. Probabilistic Curve (or data later)

- Two Parameter PCs
- 3 Confidence Levels

B. Energy System Failure Model (or data later)

- State of Electricity System
- Increase Power Load relook at state



**Box
Plots**

Feedback?

[note: not clear enough for professionals in medicine, but vital for risk experts to understand progression from box plots to to risk chart]

Jinja Regional Referral Hospital

Total: 500 hospital beds → 60,833 patients/year

4% Energy System (Grid+Diesel) Failure during the Year

45% High Impact, 20% Medium Impact, 20% Low Impact, 15% No Impact

500 beds - Size	Deaths Min	Deaths Mean	Deaths Max
Medical Procedures in High Impact: 45%	107	169	217
Medical Procedures in Medium Impact: 20%	20	37	61
Medical Procedures in Low Impact: 20%	11	18	29

Jinja Modeled Deaths

Total Yearly Deaths = 223 +/- 85 [138, 308]

Note: Newspaper claimed 150 deaths in 6 months or 300 deaths in year.

Health Care + Electricity Simulation Model

C. Medical Procedure Types:

- % of High Impact Procedures
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- % of Low Impact Procedures
- % of No Impact Procedures

D. Size of Health Care Facility

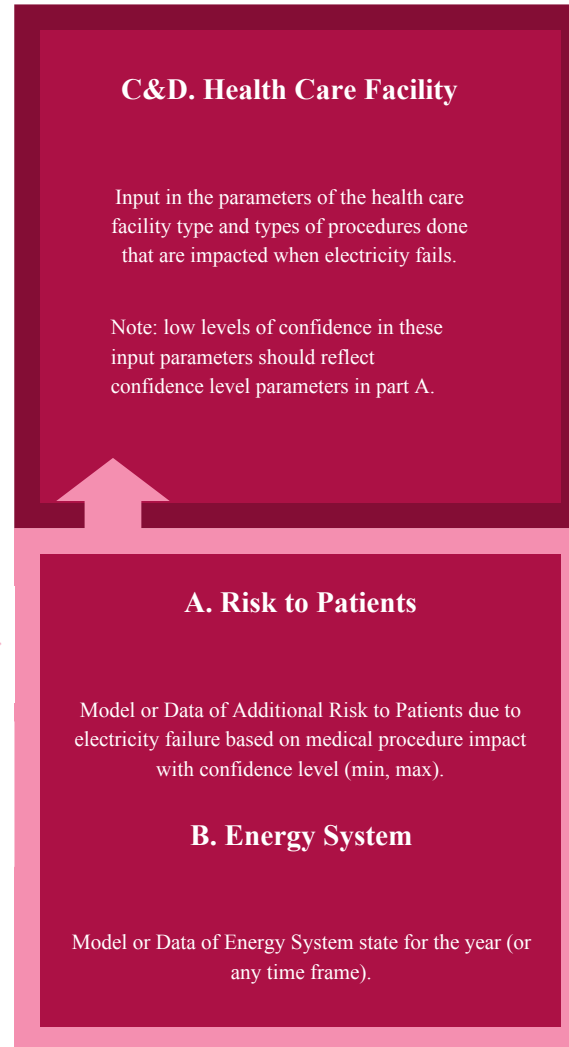
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- Increase Power Load relook at state



C&D. Health Care Facility

Input in the parameters of the health care facility type and types of procedures done that are impacted when electricity fails.

Note: low levels of confidence in these input parameters should reflect confidence level parameters in part A.

A. Risk to Patients

Model or Data of Additional Risk to Patients due to electricity failure based on medical procedure impact with confidence level (min, max).

B. Energy System

Model or Data of Energy System state for the year (or any time frame).

Risk Chart

Feedback?

Great for medical professionals to understand and to make decisions.

Solid for risk analysts in terms of traditional charts.

Good for energy system engineering designers because they can output year failure data as load increases over time as well as compare \$/kWh for LCOE and VSL/E.

Risk Chart with Days in a Year based on

Health Care Facility (Size=150 beds High=5% Med=10% Low=20% No Impacts=65%) and Energy System (Solar-Iraq designed with a LCOE of \$0.26/kWh)

S e v e r i t y	Catastrophic High Chance of 2 Deaths during Day	0	0	27	14	9
	Significant Low Chance of 2 Deaths during Day	0	0	24	2	0
	Moderate High Chance of 1 Death during Day	0	0	19	1	1
	Minor Low Chance of 1 Death during Day	0	0	14	0	0
	Negligible Extremely Low Chance of 1 Death During Day	47	121	65	11	9
<div style="display: flex; flex-direction: column; gap: 5px;"> <div> Below + considering On-demand Energy Systems</div> <div> Below + Postpone Procedures</div> <div> Below + Check Energy Stored before Starting Procedure</div> <div> No Change to Procedure*</div> <div> No Change to Procedure: Traditional Backup</div> </div>		Improbable 0-2 hrs Time in a Failure Event during Day	Remote 2-5 hrs Time in a Failure Event during Day	Occasional 5-10 hrs Time in a Failure Event during Day	Probable 10-15 hrs Time in a Failure Event during Day	Frequent 15-24 hrs Time in a Failure Event during Day
<p>* Strongly consider adding another backup system for hybridization and diversification of energy systems before risks increase.</p>		Likelihood				

Risk Chart with Days in a Year and Hidden VSL/E Costs

Health Care Facility (Size=150 beds High=5% Med=10% Low=20% No Impacts=65%) and Energy System (Solar-Iraq designed with a LCOE of \$0.26/kWh)

S e v e r i t y	Catastrophic High Chance of 2 Deaths during Day	No events \$0/kWh	No events \$0/kWh	27 Days \$24,243/kWh	14 Days \$14,996/kWh	9 Days \$9,378/kWh
	Significant Low Chance of 2 Deaths during Day	No events \$0/kWh	No events \$0/kWh	24 Days \$12,323/kWh	2 Days \$957/kWh	No events \$0/kWh
	Moderate High Chance of 1 Death during Day	No events \$0/kWh	No events \$0/kWh	19 Days \$6,728/kWh	1 Day \$412/kWh	1 Day \$412/kWh
	Minor Low Chance of 1 Death during Day	No events \$0/kWh	No events \$0/kWh	14 Days \$4,061/kWh	No events \$0/kWh	No events \$0/kWh
	Negligible Extremely Low Chance of 1 Death During Day	47 Days \$739/kWh	121 Days \$12,057/kWh	65 Days \$13,421/kWh	11 Days \$846/kWh	9 Days \$0/kWh
	<div style="display: flex; flex-direction: column; gap: 5px;"> <div> Below + considering On-demand Energy Systems</div> <div> Below + Postpone Procedures</div> <div> Below + Check Energy Stored before Starting Procedure</div> <div> No Change to Procedure*</div> <div> No Change to Procedure: Traditional Backup</div> </div>	Improbable 0-2 hrs Time in a Failure Event during Day	Remote 2-5 hrs Time in a Failure Event during Day	Occasional 5-10 hrs Time in a Failure Event during Day	Probable 10-15 hrs Time in a Failure Event during Day	Frequent 15-24 hrs Time in a Failure Event during Day
Likelihood						
* Strongly consider adding another backup system for hybridization and diversification of energy systems before risks increase.						

Any Questions?

Health Care during Electricity Failures:

Patient Risks, Capacity Shortages, VSL/E, and Risk Chart

Abigail Mechtenberg^{*1,2}, Brady McLaughlin¹, Michael DiGaetano³, Doyinsade Awodele¹,
Moses Musaaazi⁴, Lydia Nanjula^{5,6}, Mark Shrimel⁷

¹ Energy and Sustainable Development with Design Lab, Physics Department, University of Notre Dame;

² ND Energy, University of Notre Dame; ³ Rutgers New Jersey Medical School, Rutgers University

⁴ College of Engineering, Art, Design, and Technology, Makerere University;

⁵ School of Medicine, Neurosurgery, Makerere University; ⁶ Neurosurgery, Mulago Hospital;

⁷ Global Surgery and Change, Harvard University

ESDD - RESEARCH LAB

ENERGY AND SUSTAINABLE DEVELOPMENT WITH DESIGN

* Today's speaker

Back-Up Slides

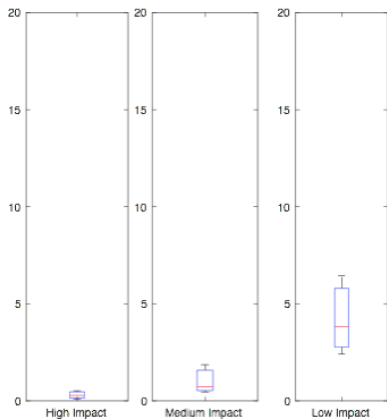


Small Health Care Facility

Total: 780 patients per year

1% High Impact, 9% Medium Impact, 70% Low Impact, 20% No Impact

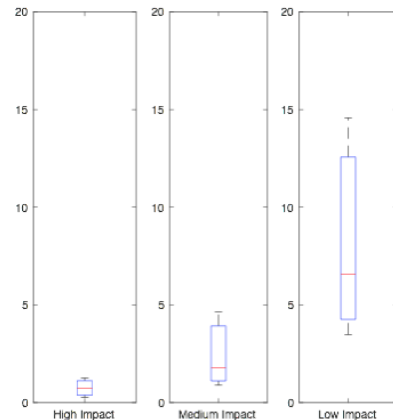
Modeled Patient Deaths for Specific Facilities



Solar Only

5/780 = 0.6 %

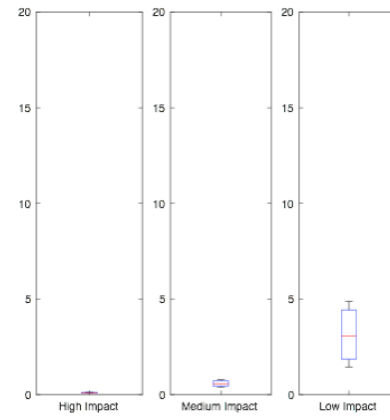
Chance of Death



Hydro Only

9/780 = 1.2 %

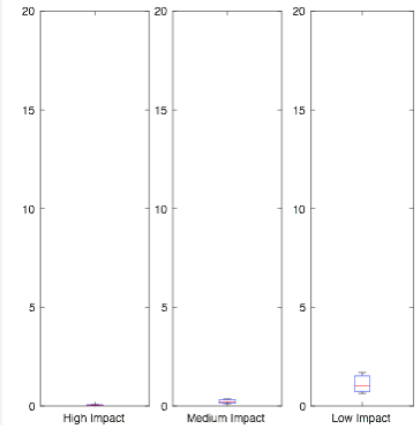
Chance of Death



Solar+Wind

4/780 = 0.5 %

Chance of Death



Grid+Diesel

1/780 = 0.1 %

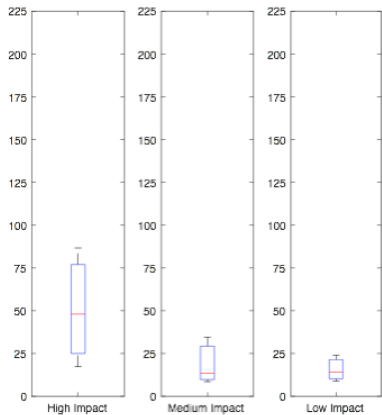
Chance of Death

Larger Health Care Facility

Total: 5200 patients per year

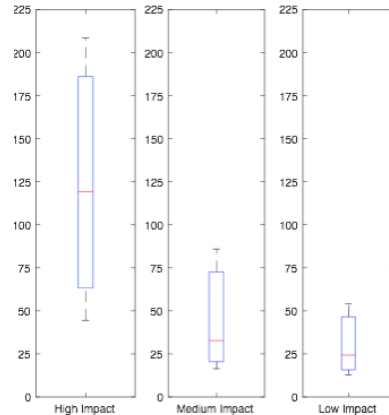
20% High Impact, 25% Medium Impact, 35% Low Impact, 20% No Impact

Modeled Patient Deaths for Specific Facilities



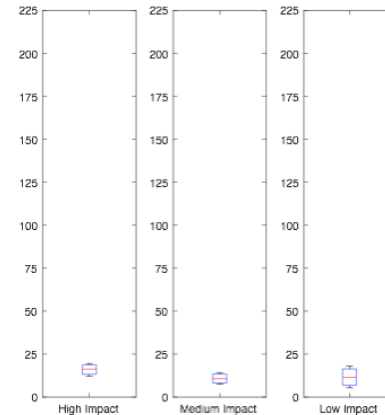
Solar Only

$76/5200 = 1.5 \%$
Chance of Death



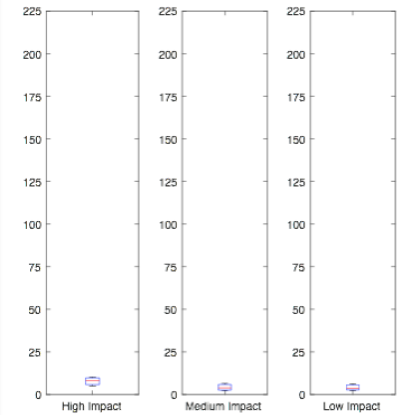
Hydro Only

$176/5200 = 3.4 \%$
Chance of Death



Solar+Wind

$38/5200 = 0.7 \%$
Chance of Death



Grid+Diesel

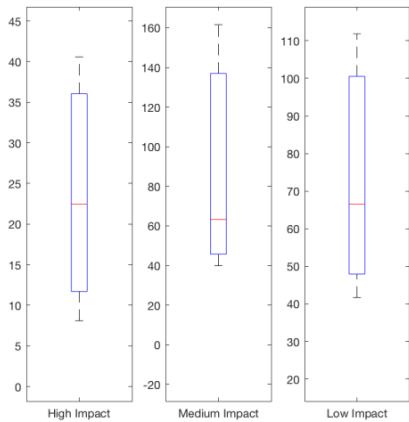
$16/5200 = 0.3 \%$
Chance of Death

Regional Hospital - Not Referral

Total: 500 hospital beds → 60,833 patients/year

1% High Impact, 10% Medium Impact, 20% Low Impact, 69% No Impact

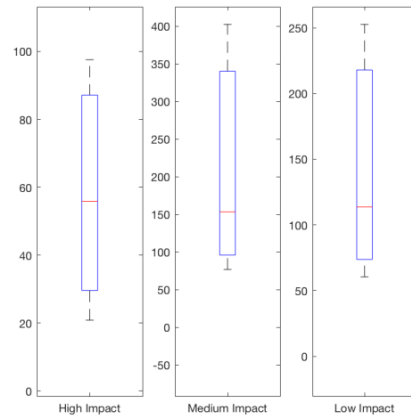
Modeled Patient Deaths for Specific Facilities



Solar Only

153 → 0.3 %

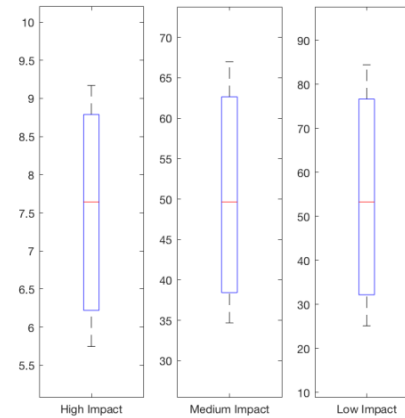
Chance of Death



Hydro Only

323 → 0.5 %

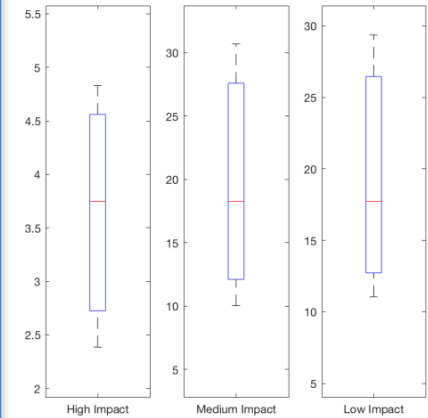
Chance of Death



Solar+Wind

110 → 0.2 %

Chance of Death



Grid+Diesel

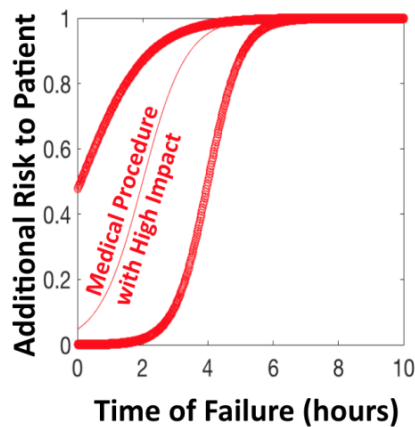
40 → 0.1 %

Chance of Death

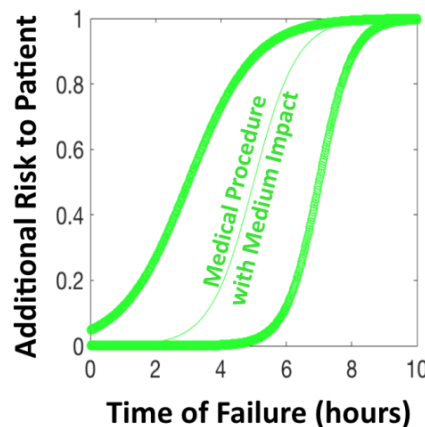
(k_j, c_i)

$$r_{ij}(t_{failure}) = \frac{1}{1 + \exp(-k_j(t_{failure} - c_i))}$$

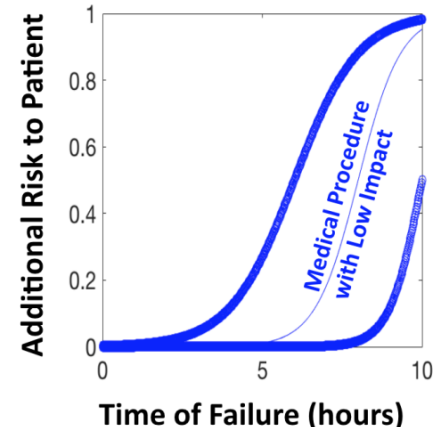
k_{High}, c_{1-i}	k_{Med}, c_{2-i}	k_{Low}, c_{3-i}
(1, 0.1)	(1.5, 2)	(2, 4)
(1, 3.0)	(1.5, 5)	(2, 7)
(1, 6.0)	(1.5, 8)	(2, 10)



$$r_{High}(t) = \frac{1}{1 + \exp(-(t - c_{123}))}$$

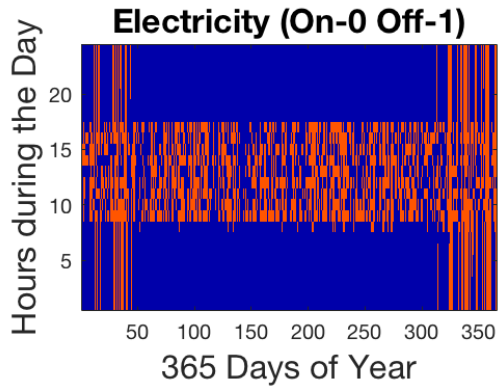


$$r_{Med}(t) = \frac{1}{1 + \exp(-1.5(t - c_{123}))}$$



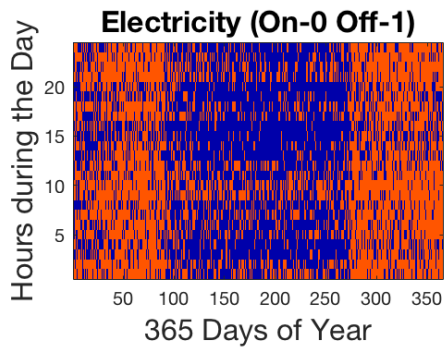
$$r_{Low}(t) = \frac{1}{1 + \exp(-2(t - c_{123}))}$$

Note: six other probabilistic two parameter functions modeled as well. Ask for more details - simulation model is flexible!

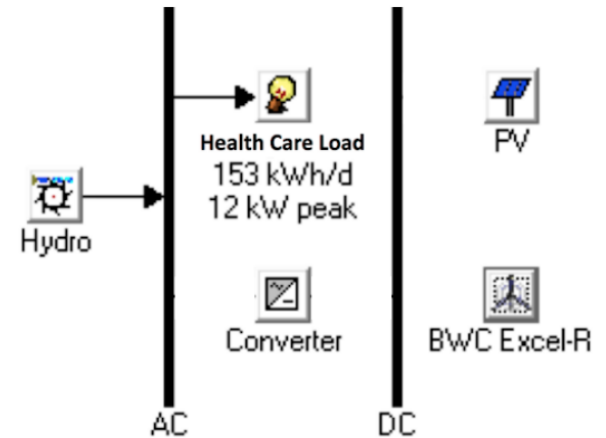


Iraq - Solar Energy, 2010	
Cost of Electricity (\$/kWh)	\$0.26/kWh
Energy Capacity Shortage (%) $\frac{E_{not\ served}}{E_{total}}$	18 %
Time Capacity Shortage (%) $\frac{t_{not\ served}}{t_{total}}$	25 %
Failures (hrs/year)	2160 hours
Back-up System	Install Solar no backup chosen

Country: Iraq – Optimal energy system was chosen as solar panel and batteries.

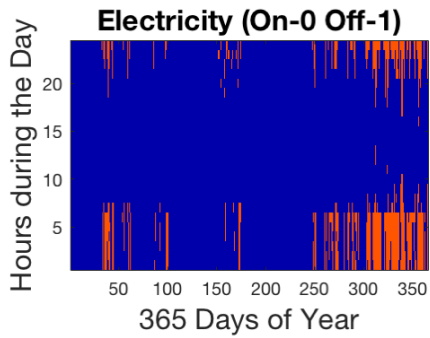


Ghana - *International Journal of Computer Applications*, 2015



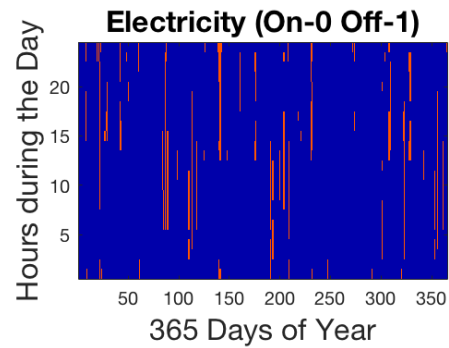
Cost of Electricity (\$/kWh)	\$0.12/kWh
Energy Capacity Shortage (%) $\frac{E_{not\ served}}{E_{total}}$	11 %
Time Capacity Shortage (%) $\frac{t_{not\ served}}{t_{total}}$	49 %
Failures (hrs/year)	4289 hours
Back-up System	Government Grid: Hydro base power, Facilities: Provide their own peak power

Country: Ghana – Optimal energy system was chosen as hydroelectricity



	Bangladesh - <i>Energy</i> , 2010
Cost of Electricity (\$/kWh)	\$0.51/kWh
Energy Capacity Shortage (%) $\frac{E_{not\ served}}{E_{total}}$	10 %
Time Capacity Shortage (%) $\frac{t_{not\ served}}{t_{total}}$	6.6 %
Failures (hrs/year)	574 hours
Back-up System	Install Solar+Wind no backup chosen

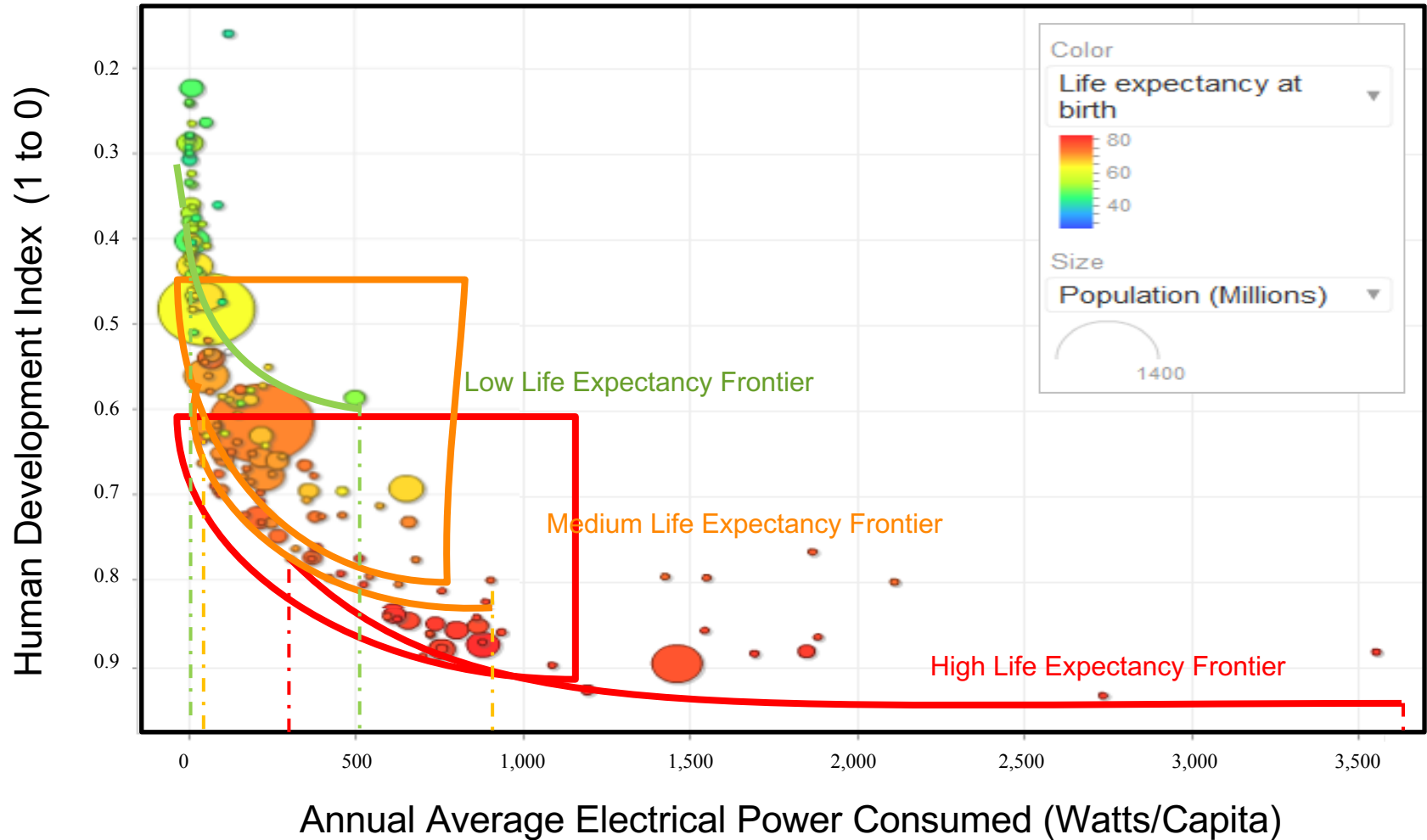
Country: Bangladesh – Optimal energy system was chosen as solar panel and wind.



Uganda - <i>ISSST-IEEE</i> , 2012	
Cost of Electricity (\$/kWh)	Grid: \$0.25/kWh - Diesel: \$0.75-11/kWh
Energy Capacity Shortage (%) $\frac{E_{not\ served}}{E_{total}}$	4.1 %
Time Capacity Shortage (%) $\frac{t_{not\ served}}{t_{total}}$	4.0 %
Failures (hrs/year)	355 hours
Back-up System	Year of Data on Voltage and Current Grid+Diesel Generator

Three Electricity and HDI Frontiers

(EIA, UNDP, UN-Population 2006 Data)



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Empower Energy Design and Jersey City Board of Education
Empower Energy Design and Jersey City Board of Education

ENERGY AND SUSTAINABLE DEVELOPMENT WITH DESIGN

(734) 719 0432 | e-mail: empowerdesignenergy@gmail.com

Energy E³ - Talk Outline

1. Health Care Context
5. Health Care Hidden Costs

2. Energy E³ Uganda
Energy Education, Engineering Design, & Entrepreneurship



3. Energy E³ United States
Energy Education, Engineering Design, & Entrepreneurship

4. Propagation Model
Uganda Energy E³
Innovation Centers
US Energy E³
Vocational Education

Energy E³ Innovation

Changing Design
Paradigm

STOP

Design **FOR**
the other 90%¹

Design **WITH**
the other 90%²

GO

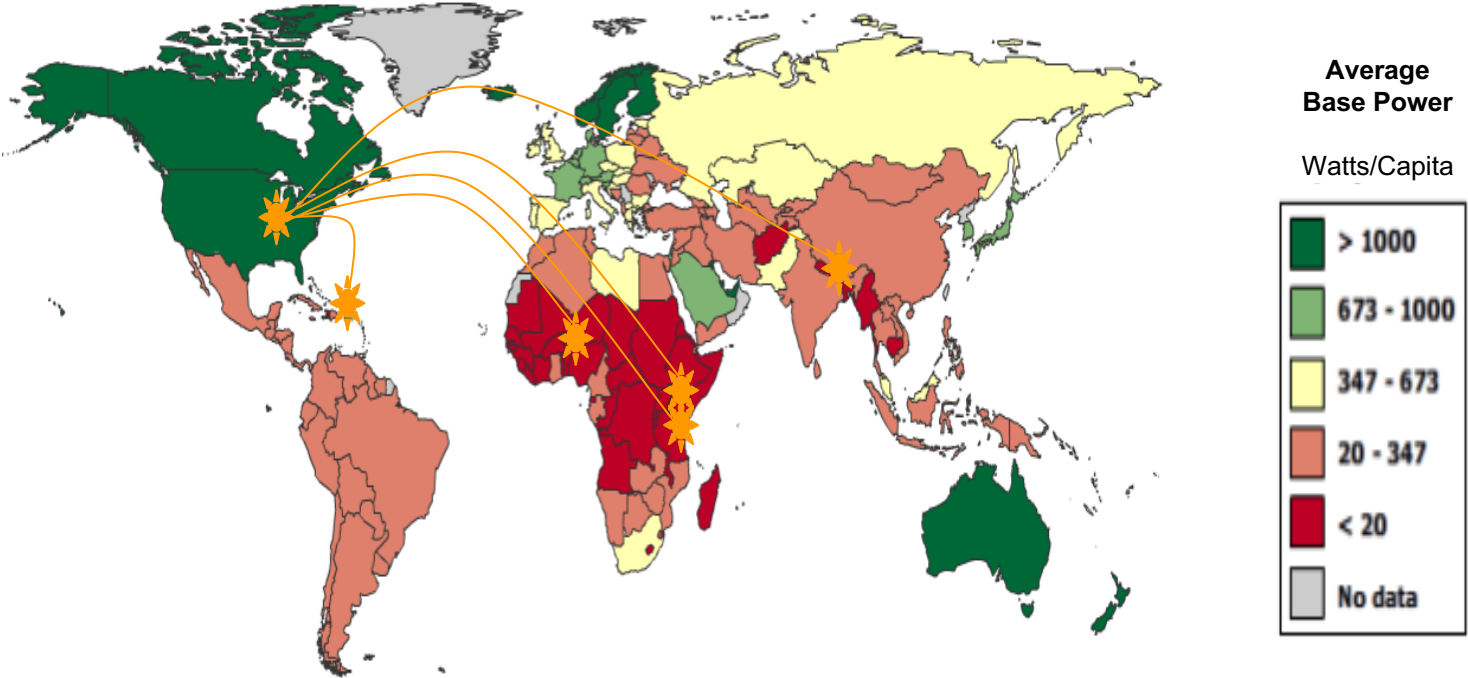
Design **BY** All³



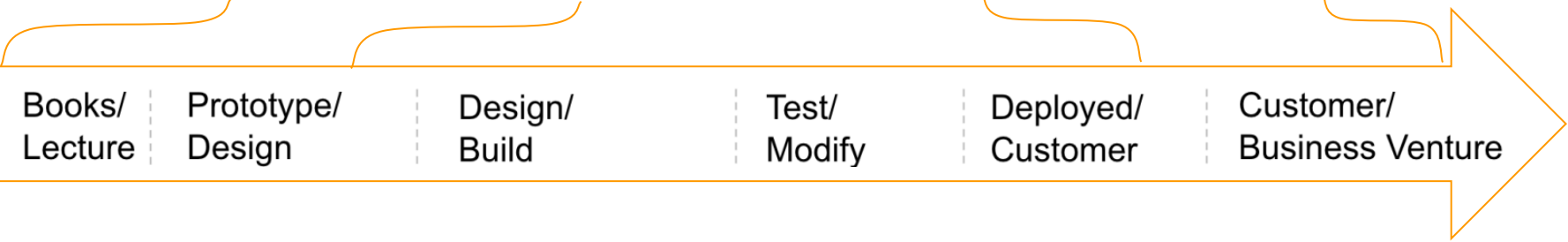
Dr. Moses
Musaazi
One of the most famous engineering designers in SSA
and yet majority of institutions fund outsiders. Why?

- ¹ Smith, Cynthia E. *Design for the Other 90%*. New York: Smithsonian, Cooper-Hewitt, National Design Museum, 2007. Print.
- ² Smith, Cynthia E. *Design with the Other 90%: Cities*. New York: Cooper-Hewitt National Design Museum, 2011. Print.
- ³ Musaazi, Moses Kizza, Abigail R. Mechtenberg, Juliet Nakibuule, Rachel Sensenig, Emmanuel Miyingo, John Vianney Makanda, Ali Hakimian, and Matthew J. Eckelman. "Quantification of Social Equity in Life Cycle Assessment for Increased Sustainable Production of Sanitary Products in Uganda." *Journal of Cleaner Production* (2013).

Global Context + Energy E³ Pathway



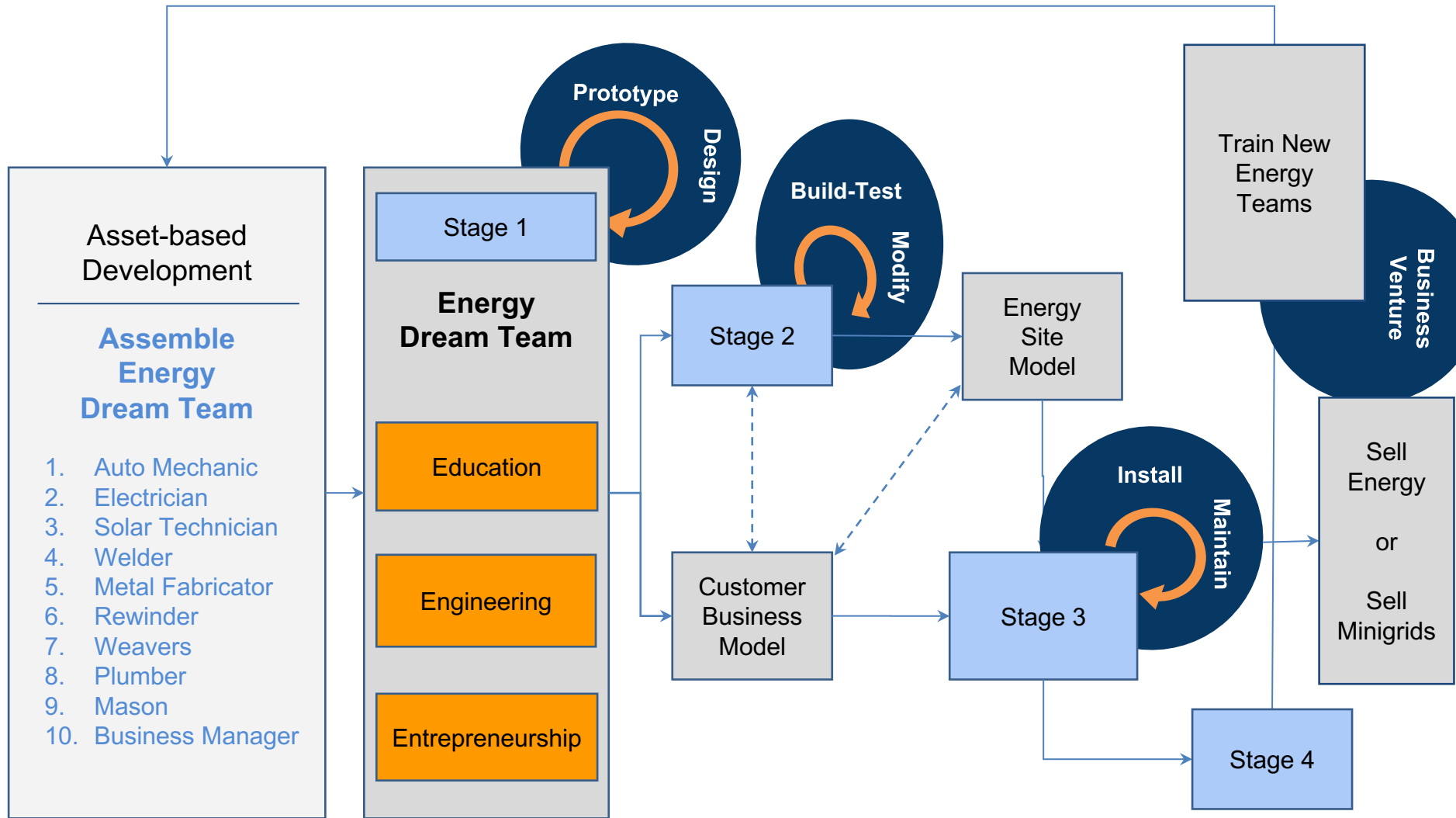
**Energy E³ Pathway =
Energy Education + Engineering Design + Entrepreneurship**



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ENERGY AND SUSTAINABLE DEVELOPMENT WITH DESIGN

Energy E³ Pathway In Action



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ENERGY AND SUSTAINABLE DEVELOPMENT WITH DESIGN

Energy E³ Devices

Mechanical to Electrical



Gravity Generator
1mW-5 W



Hand-crank Generator
50-250 W



Bicycle Generator
50-250 W



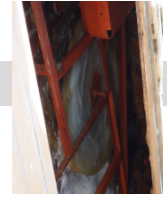
Merry-go-round Generator
100-750 W



VAWT Generator
1-50 kW



HAWT Generator
1-50 kW



Hydro Generator
1-50 kW

Thermal to Electrical & Chemical to Thermal



Thermal Electric Co-Gen Cookstove*
1-100 W



Waste Incinerator Generator*
1-50 kW



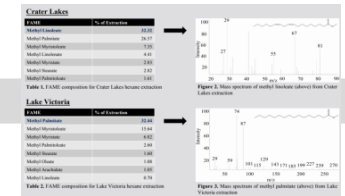
Concentrating Solar Power*
5-50 kW



Biogas Cooking

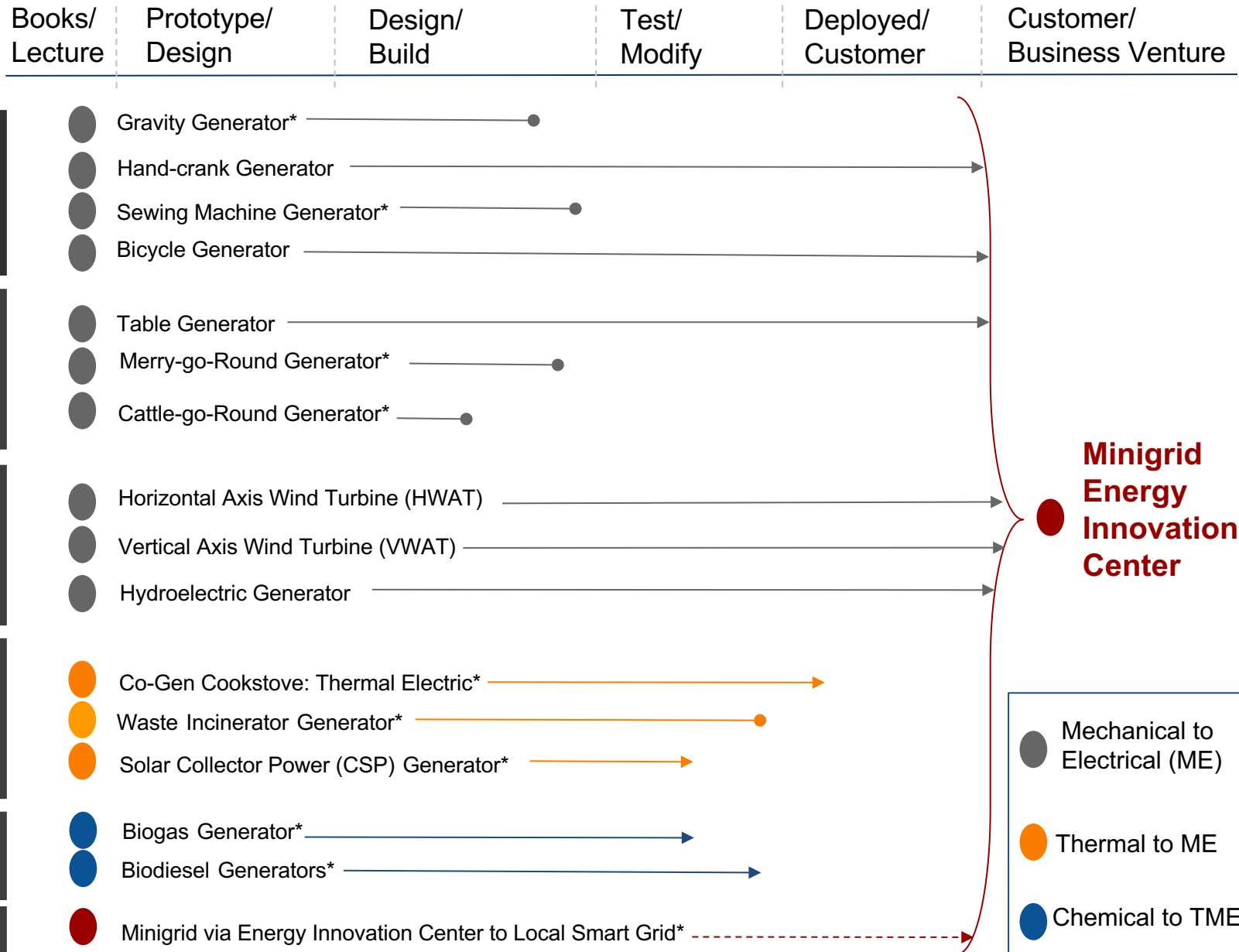


Biogas to Petrol Generator*
5-50 kW



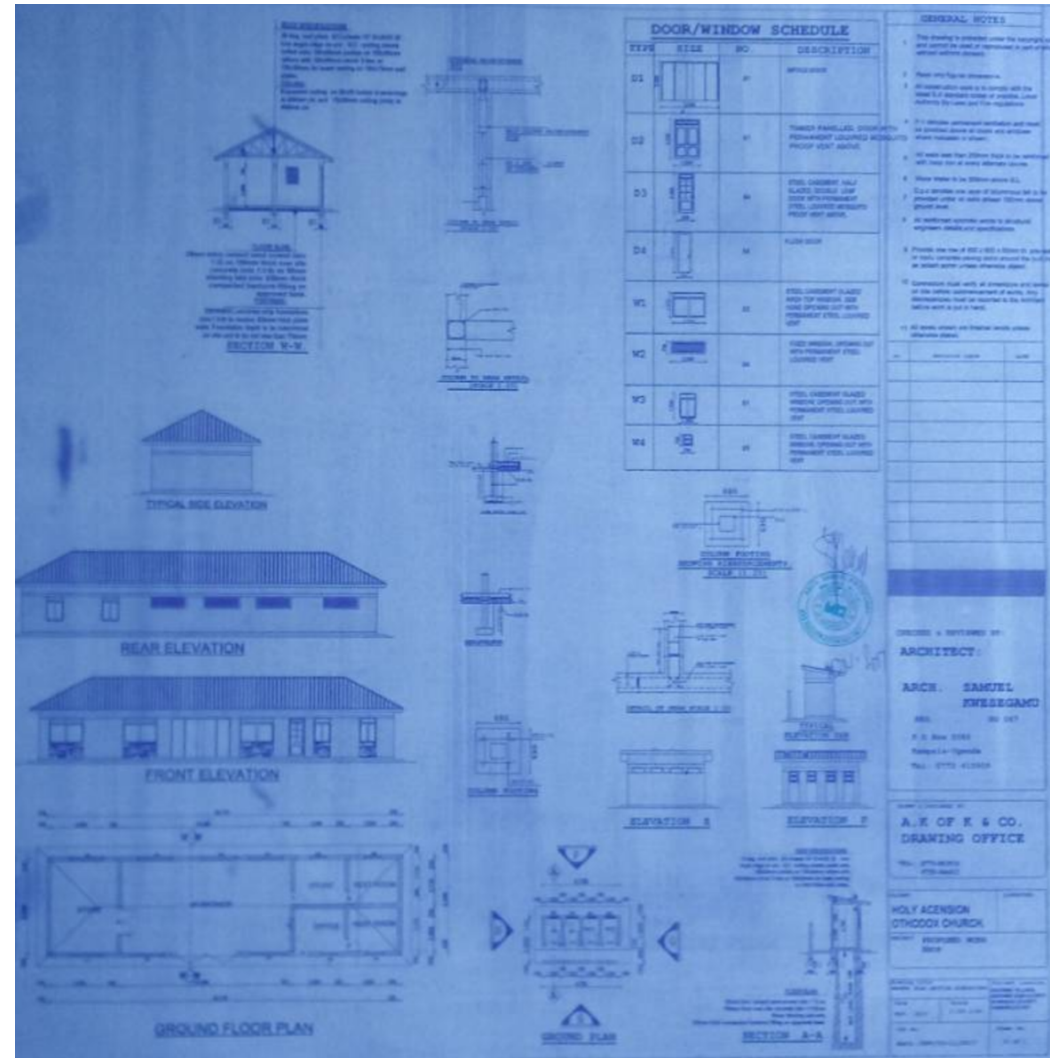
Algae into Biodiesel*
5-50 kW

Education-Engineering-Entrepreneurship Pathway



Energy E³ Innovation Center

- Display E³ Minigrid Devices
- Design/Build/Test/Modify/Control/Deploy Innovations
- Training Facility
- Educational Outreach Site
- Host Business Accelerator
- Host Trade Shows
- Attract Local Investors
- Propagate E³ Innovations

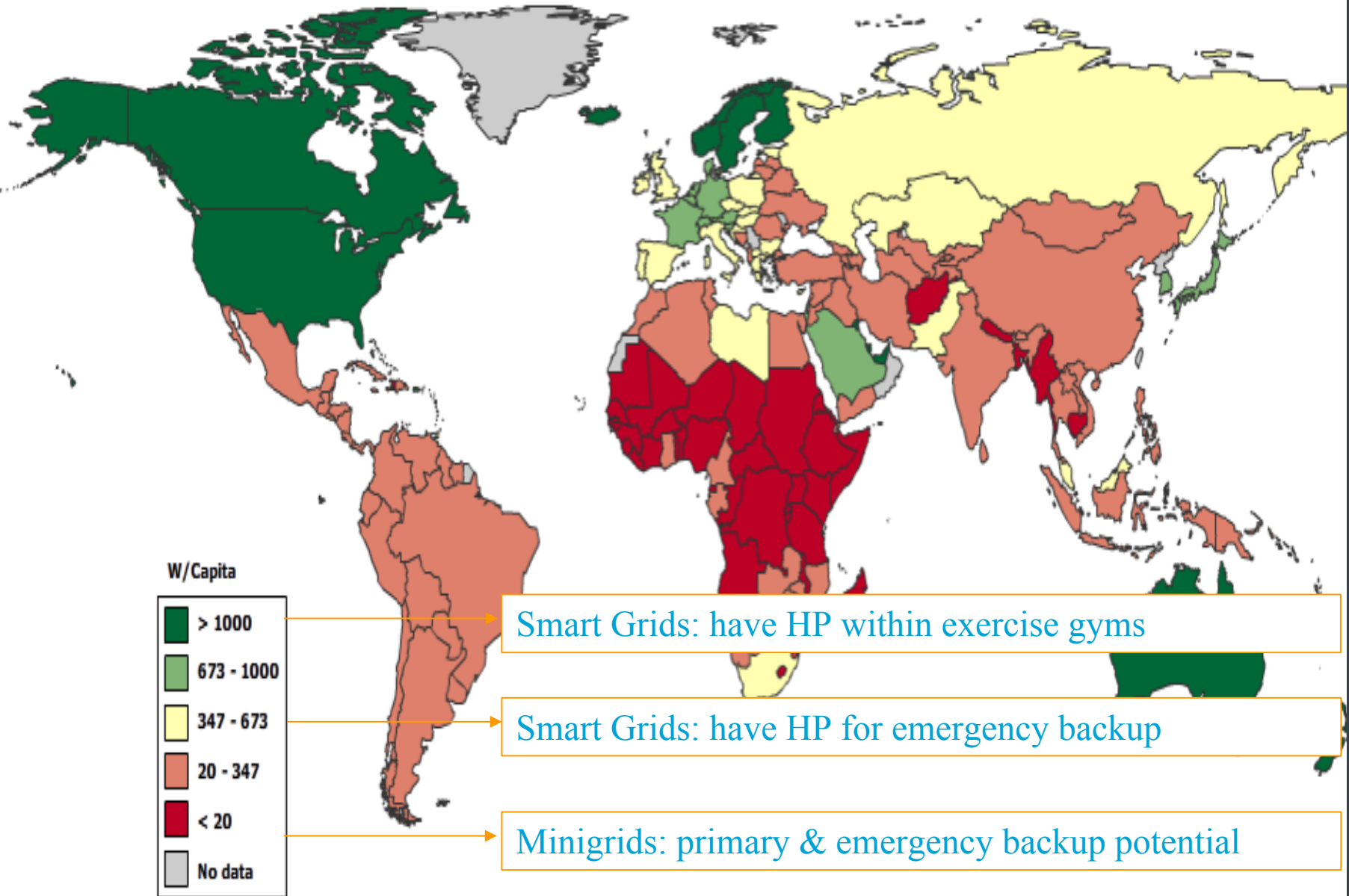


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ENERGY AND SUSTAINABLE DEVELOPMENT WITH DESIGN

Electricity World Map

(EIA, UNDP, UN-Population 2008 Data)



Energy E³ - Talk Outline

1. Health Care Context
5. Health Care Hidden Costs

2. **Energy E³ Uganda**
Energy Education, Engineering Design, & Entrepreneurship

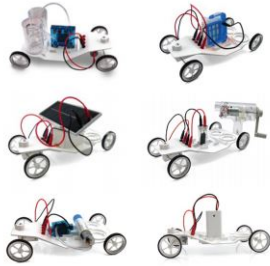


3. **Energy E³ United States**
Energy Education, Engineering Design, & Entrepreneurship

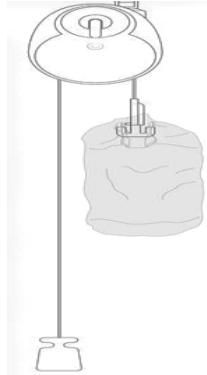
4. **Propagation Model**
Uganda Energy E³
Innovation Centers
US Energy E³
Vocational Education

US 6-12: Physics of Energy

Experimental Design Approach: Education, Engineering Design, and Entrepreneurship



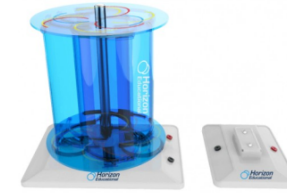
Kinematics
Energy Types



Gravity:
PE_{gravity} to Electric



HAWT
KE_{wind} to Electric



VAWT
KE_{wind} to Electric



Hydroelectric
PE or KE to Electric



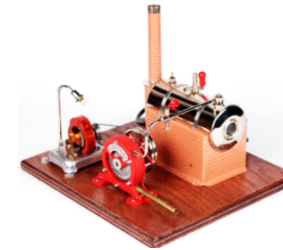
Solar Panels
Light to Electric



Transparent CSP
Light to TM to Electric



Thermal Electric



Power Plants
Steam Engine



Minigrid
Combining all+storage



US 6-12: Pulley-Mass of the pulley using two masses

Research Question: How will different masses affect the mass of the pulley?

Hypothesis: The masses hung from the string will not have an affect on the mass of the pulley.

Measure: What: Radius, Distance, Time, Mass

Measure: How:

- Motion Detector
- Ruler
- Scale

Calculate: What: Mass of pulley, Acceleration

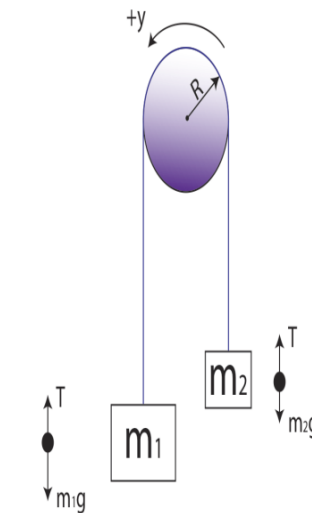
Calculate: How: Equations

- $m = 2 \sum (\tau / ra)$
- $\tau = Fr \sin \theta$
- $F = ma,$
- $a = v^2 / r$

Vary: Time to hit ground by varying the masses
(12 trials 10/20g, 20/40g, 30/50g, 50/100g, 100/200g)

Constant: -The pulley type
-String length

Analysis Pathway: Graphical analysis of time versus change in mass



Laptop



Motion Detector



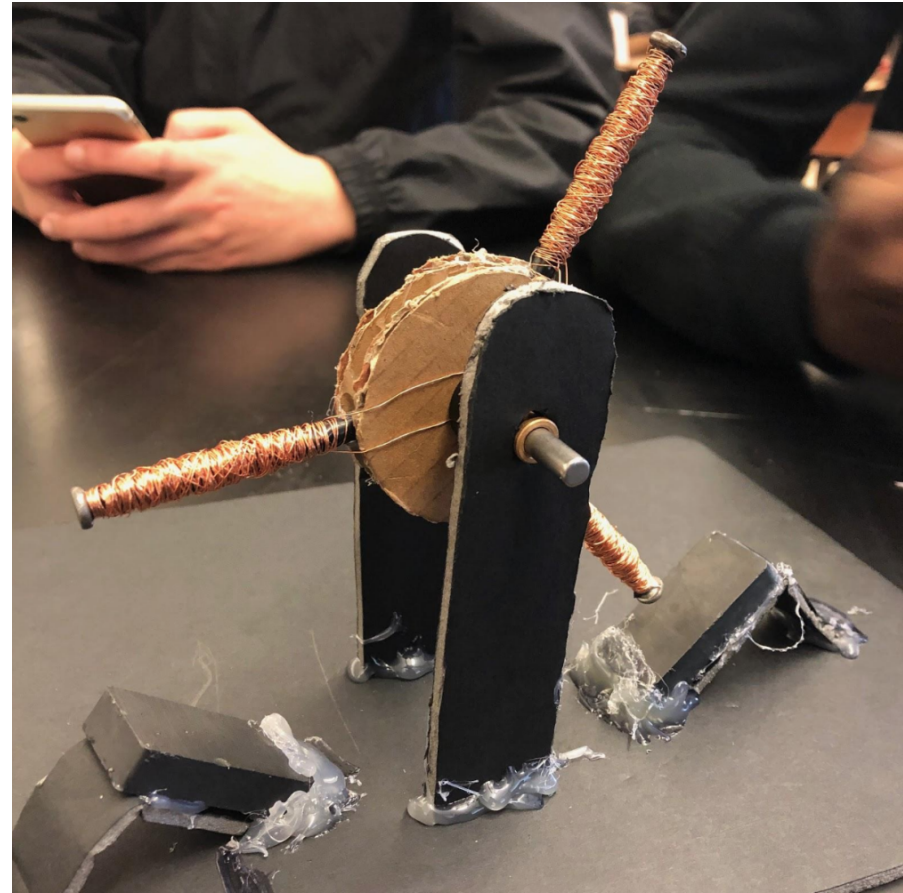
Labquest 2

Physics of Energy to Engineering Design

Mechanical: Mass-Pulley of Gravity Light Part 1



Electrical: Generator of Gravity Light Part 2



Real Energy Systems Designed by Rwandans

CLOSED

GravityLight: lighting for developing countries.

Please click the link below to see our brand new campaign - GravityLight 2: Made in Africa

PROJECT OWNER



\$399,590 USD raised by 6219 backers

CLOSED

GravityLight 2: Made in Africa

We believe in safe & clean light for all. Pledge now for a GravityLight & help make this a reality.

PROJECT OWNER



\$401,077 USD total funds raised
128% funded on July 18, 2015

INDEMAND

nowlight: the next generation GravityLight

Create instant light and power with the pull of a cord. 1 minute pulling generates 3 hours of light!

PROJECT OWNER



\$151,623 USD total funds raised
147% funded on July 1, 2018



Power Output (12.5kg Load)

High: 0.10W

Med: 0.075W

Low: 0.05W

LED

Power (max): 124mW

Operating Temp: -30 ~80 °C

Storage Temp: -40 ~100 °C

Luminous Intensity: 13.8 cd*

Product Dims

Weight: 0.8kg

H:160mm, **W:**103mm, **D:**78mm

Load Weight

Minimum: 8.0kg

Maximum: 12.5kg

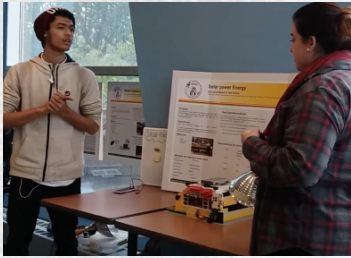
* Luminous intensity value as per CIE 127:2007 standard (If=20mA)

Published Total: almost \$1,000,000 for a device with a LCOE of \$20,000/kWh (from \$75 cost)

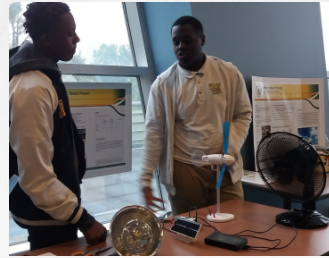
Does not include what Shell has given them to design for “the Other 90%”.

Gaju Gatera’s University of Rwanda Energy E3 team has designed energy systems better than this.

US 6-12: Physics Labs to Experimental Design EXPO



Solar House



Solar + Wind



Circuit Scribe



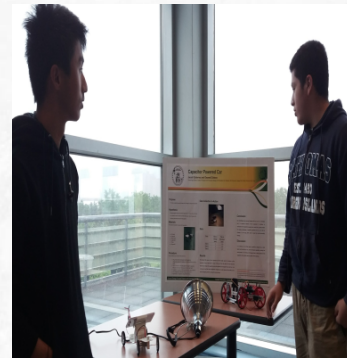
Presentations



Congratulations



Fermentation



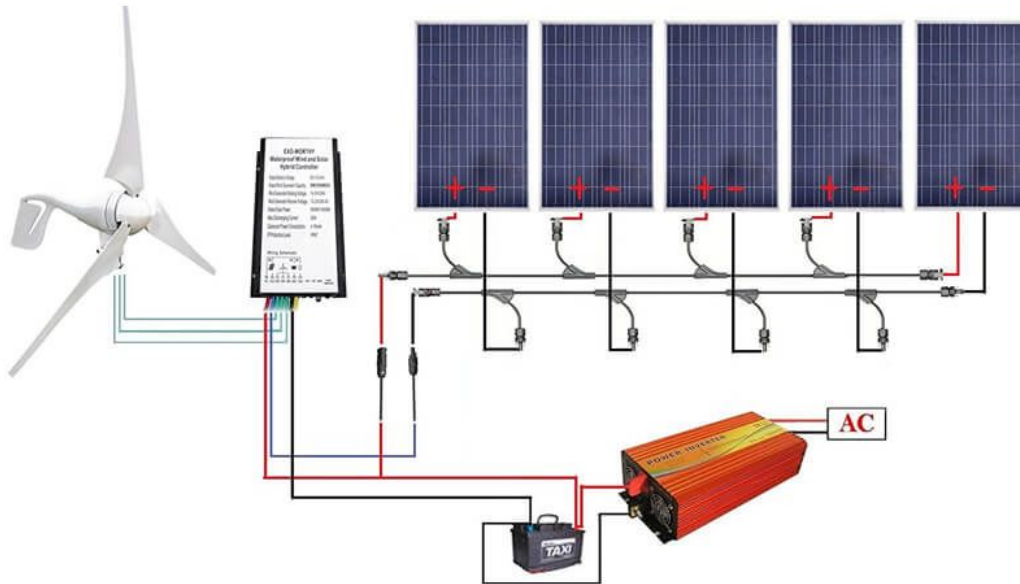
Solar Car



MudWatt



MiniGrid Build after EXPO With 80/20



Source Image 1: Ecoworthy



Source Image 2: Solar Mill, WindStream Technologies

Sample Images from other projects

- our pictures come this summer with our first built minigrd by this US - Energy E3 Program.

Note: picture to the right appears to also use 80/20.

